



Snowmass Energy Frontier

ILC Analysis Walkthrough

Daniel Jeans / KEK

Chris Potter / U. Oregon

on behalf of ILC physics & software groups

2020-October-14



beautiful views
&
fresh perspectives

our goal



storm clouds ?

our goal

vertical cliffs?

hidden gullies ?

bears?

snakes ?



hints on how to survive a 2 hour tutorial

1. stay hydrated



2. ask questions at any time

???

Introduction

<http://ilcsnowmass.org/>

MC/Simulation Framework Tutorial: ILC

August 28, 2020
US/Eastern timezone

<https://indico.fnal.gov/event/45031/>

MC/Simulation Framework Tutorial: Whizard for e+e-

September 29, 2020
Asia/Tokyo timezone

<https://indico.fnal.gov/event/45413/>

MC/Simulation Framework Tutorial: ILC Analysis Walkthrough

October 14, 2020
US/Eastern timezone

<https://indico.fnal.gov/event/45721/>

quiz to help us understand you, our audience:

Q. raise your hand if you attended

MC/Simulation Framework Tutorial: ILC

August 28, 2020

US/Eastern timezone

quiz to help us understand you, our audience:

Q. raise your hand if you attended

MC/Simulation Framework Tutorial: Whizard for e+e-

September 29, 2020

Asia/Tokyo timezone

quiz to help us understand you, our audience:

Q. raise your hand if you are a grad student

Q. raise your hand if you are a post-doc

Q. raise your hand if you are staff / professor

quiz to help us understand you, our audience:

Q. raise your hand if you are a grad student

Q. raise your hand if you are a post-doc

Q. raise your hand if you are staff / professor

quiz to help us understand you, our audience:

Q. raise your hand if you are a grad student

Q. raise your hand if you are a post-doc

Q. raise your hand if you are staff / professor

quiz to help us understand you, our audience:

Q. raise your hand if you have an account on
login.snowmass21.io

there will be some practical examples,
can run from login.snowmass21.io or
your own machine (preferably centos7 + cvmfs)

if you are using your own machine, can you see
`/cvmfs/ilc.desy.de/sw/x86_64_gcc82_centos7/v02-02/init_ilcsoft.sh` ?
→ if not, do you have `lcio` and `ROOT` installed?

quiz to help us understand you, our audience:

write us a zoom message with your physics interest
(whether at ILC or other)

today we'll build on the past tutorials

but we'll try to be self-contained,
so don't worry if you've forgotten some things

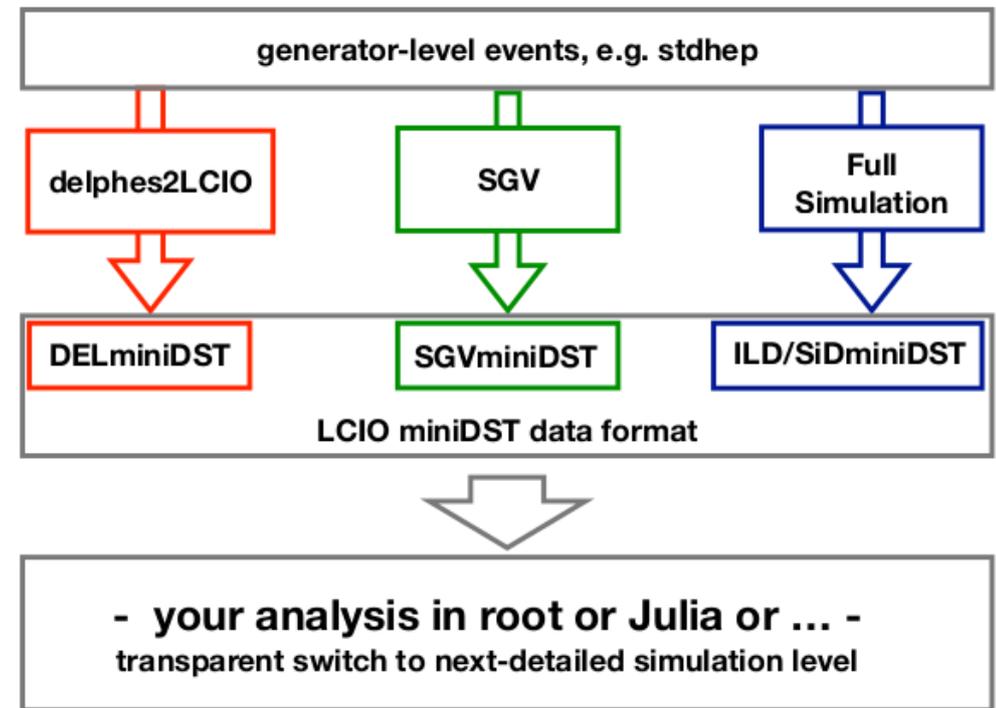
- review how to generate a BSM signal@ILC using WHIZARD [Daniel]
- how to apply DELPHES ILC detector simulation [Chris]
- how to analyse those data in ROOT, [Daniel]
get the event information you need
deal with beam polarization and luminosity
estimate SM background

future directions: analysis techniques,
more sophisticated detector simulation, ...

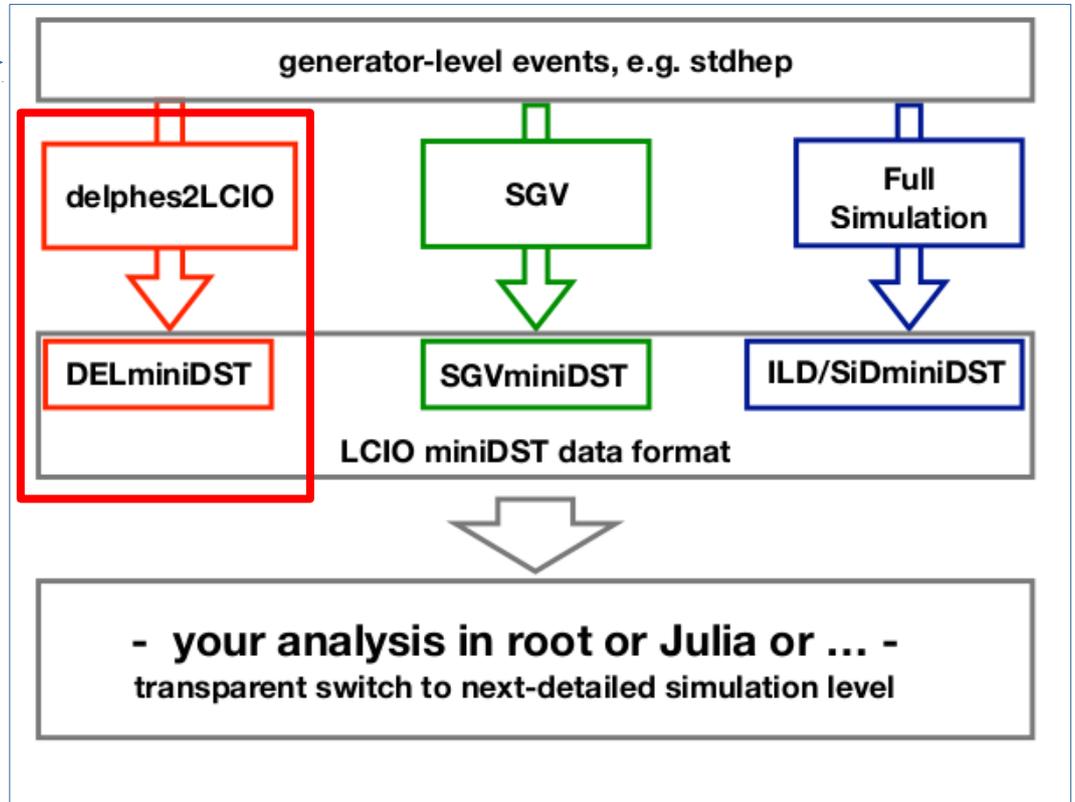


Parametrised, fast and full (=geant4-based) simulations

- **delphes2lcio**: an lcio application which makes Delphes (parametrised detector simulation) write out LCIO (<https://github.com/iLCSoft/LCIO/tree/master/examples/cpp/delphes2lcio>)
- **SGV**: **S**imulation a **G**rande **V**itesse (https://www.desy.de/~berggren/sgv_ug/sgv_ug.html) - detailed fast simulation from "first principles" (nearly no parametrisations!)
- **iLCSoft** (<https://github.com/iLCSoft>): software suite for full simulation and reconstruction of ILC & CLIC detectors

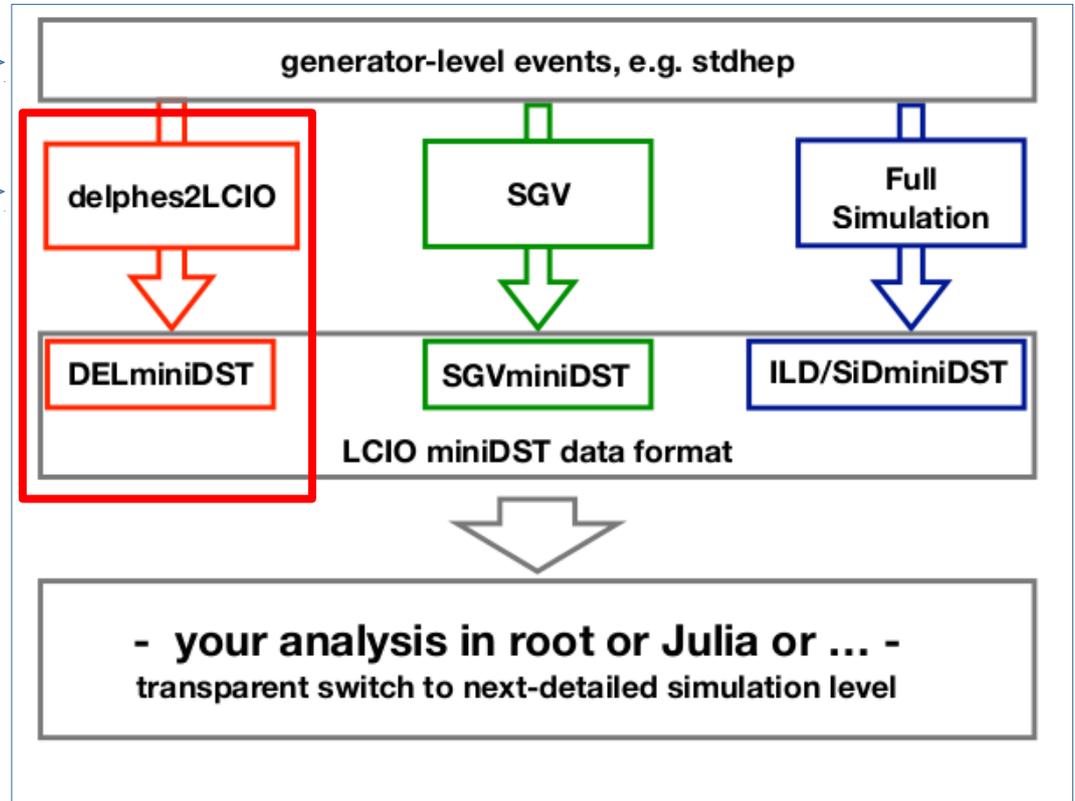


part 1: WHIZARD



part 1: WHIZARD →

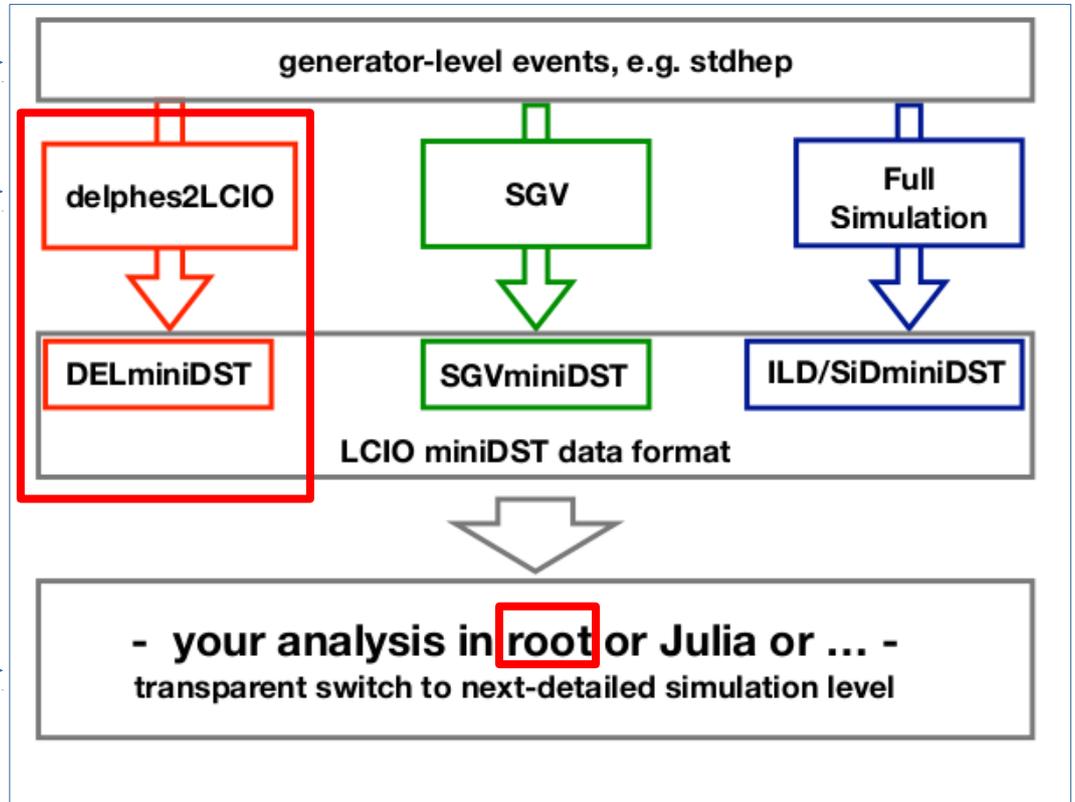
part2: delphes2LCIO →



part 1: WHIZARD →

part2: delphes2LCIO →

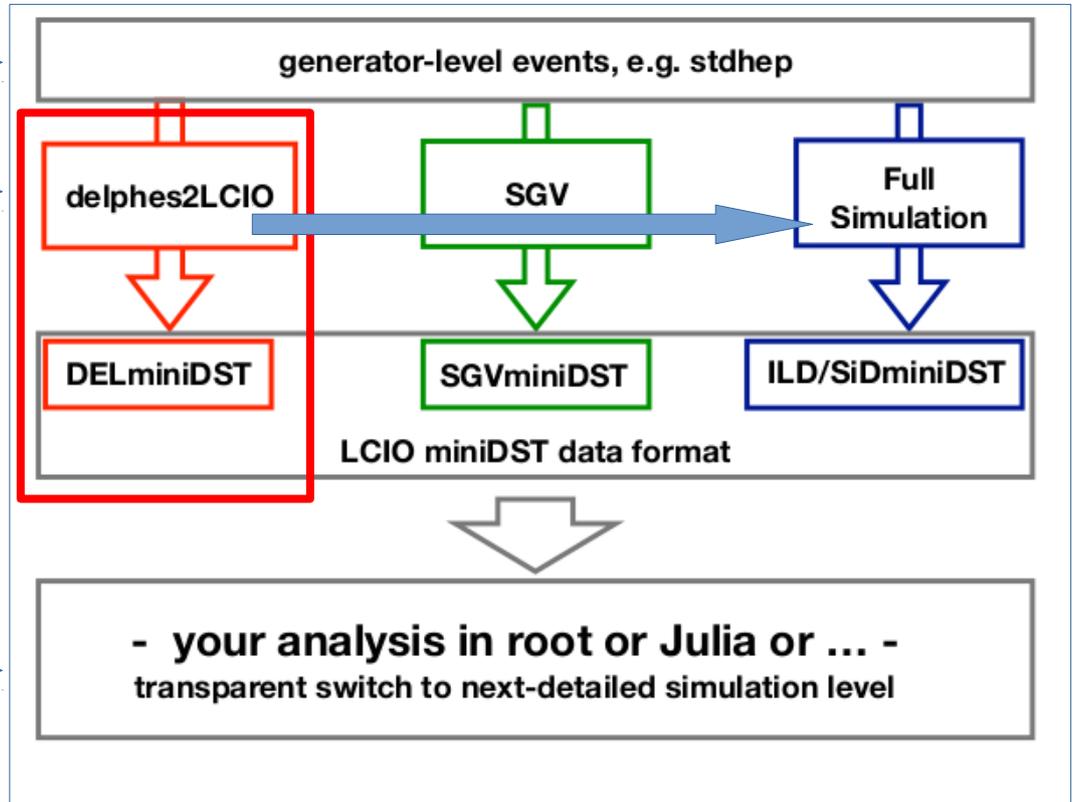
part3: analysis →



part 1: WHIZARD →

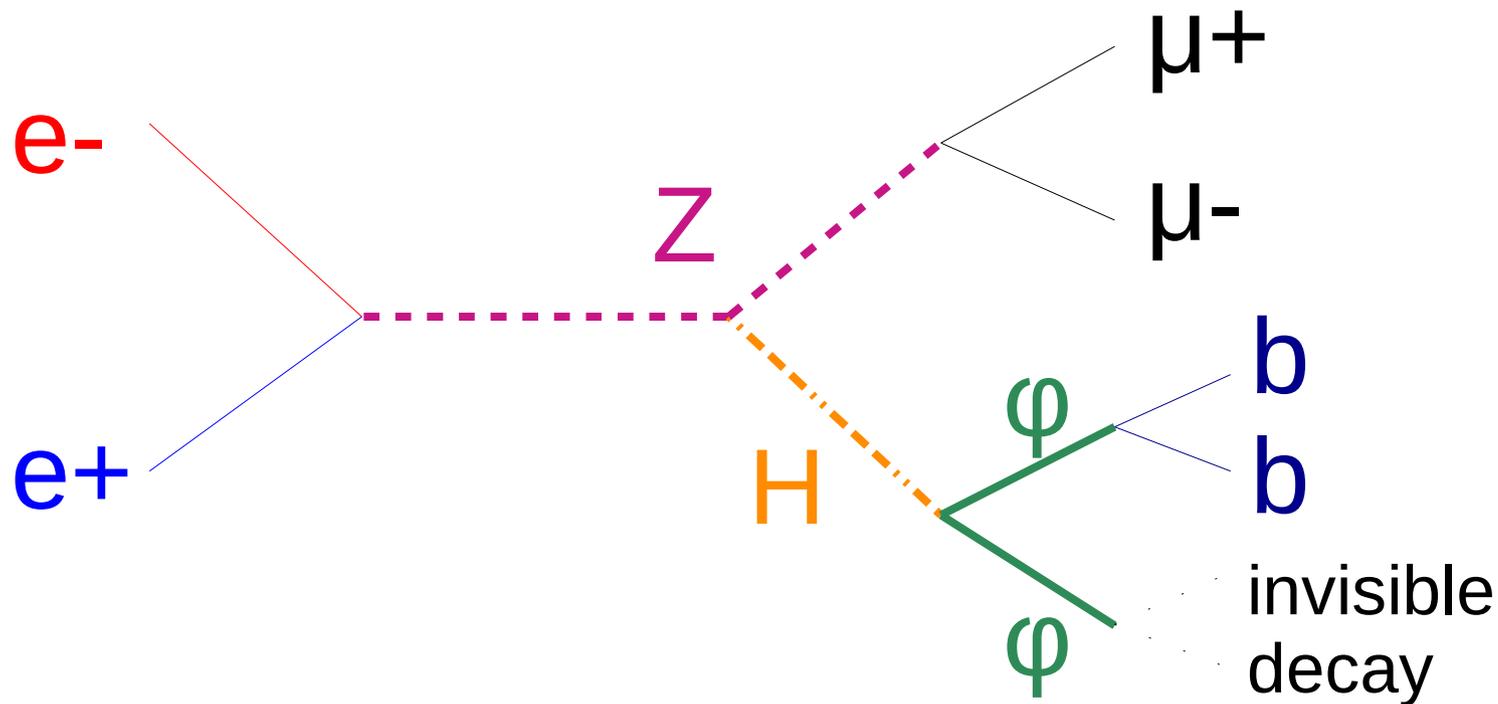
part2: delphes2LCIO →

part3: analysis →



+ increased realism

today we'll investigate sensitivity to this exotic H decay
at ILC-250



$\varphi \rightarrow$ some new scalar

part 1: generate the signal

(we'll skip doing this in real time for time reasons)

WHIZARD@e+e- tutorial

<https://indico.fnal.gov/event/45413/>

<https://whizard.hepforge.org/>

```
model = "2HDM" (ufo)
```

```
!! Show particle content and couplings of '2HDM'  
show (model)
```

```
mh1 = 125 GeV  
mh2 = 40 GeV  
mh3 = 40 GeV
```

the WHIZARD steering file (in sindarin)

```
process eemumuhh = "e-", "e+" => "mu+", "mu-", "h2", "h3" { $restrictions = "3+4~Z && 5+6~h1" }  
process h2dec = h2 => "vm", "vm~", "vt", "vt~"  
process h3dec = h3 => "b", "b~"
```

```
unstable h2(h2dec)  
unstable h3(h3dec)
```

```
?ps_fsr_active = true  
?hadronization_active = true  
$shower_method = "PYTHIA6"  
$ps_PYTHIA_PYGIVE = "MSTJ(28)=2;PMAS(25,1)=2000.0;PMAS(25,2)=10.0;MSTJ(41)=2; MSTU(22)=20; PARJ(21)=0.40000; PARJ(41)=0.11000;  
PARJ(42)=0.52000; PARJ(81)=0.25000;PARJ(82)=1.90000; MSTJ(11)=3; PARJ(54)=-0.03100; PARJ(55)=-0.00200;PARJ(1)=0.08500; PARJ(3)=0.45000;  
PARJ(4)=0.02500; PARJ(2)=0.31000;PARJ(11)=0.60000; PARJ(12)=0.40000; PARJ(13)=0.72000; PARJ(14)=0.43000;PARJ(15)=0.08000; PARJ(16)=0.08000;  
PARJ(17)=0.17000; MSTP(3)=1; MSTP(125)=2; MWID(25)=2"
```

```
beams = "e-", "e+" => circe2 => isr
```

```
$circe2_file = "ilc250.circe"  
$circe2_design = "ILC"  
?circe2_polarized = false
```

```
beams_pol_density = @(-1), @(+1)  
beams_pol_fraction = 100%, 100%
```

```
!! Set  $\alpha(0)$  for ISR splitting  
isr_mass = 0.5109989500E-03 GeV  
isr_alpha = 1/137.035999084
```

```
sqrts = 250 GeV
```

```
integrate (eemumuhh)
```

```
n_events = 10000  
$sample = "eeZH_m10_LR"  
sample_format = stdhep, lcio
```

```
!! Generate events with exclusive ISR photons.  
?isr_handler = true  
$isr_handler_mode = "recoil"
```

```
?keep_remnants = true  
?keep_beams = true  
?hadronization_active = true
```

```
simulate (eemumuhh)
```

```
model = "2HDM" (ufo)
```

```
!! Show particle content and couplings of '2HDM'  
show (model)
```

```
mh1 = 125 GeV  
mh2  
mh3
```

```
proc  
proc  
proc
```

```
unst  
unst
```

```
?ps_  
?had  
$sho  
$ps_
```

```
PARJ(42)=0.52000; PARJ(81)=0.25000;PARJ(82)=1.90000; MSTJ(11)=3; PARJ(54)=-0.03100; PARJ(55)=-0.00200;PARJ(1)=0.08500; PARJ(3)=0.45000;  
PARJ(4)=0.02500; PARJ(2)=0.31000;PARJ(11)=0.60000; PARJ(12)=0.40000; PARJ(13)=0.72000; PARJ(14)=0.43000;PARJ(15)=0.08000; PARJ(16)=0.08000;  
PARJ(17)=0.17000; MSTP(3)=1; MSTP(125)=2; MWID(25)=2"
```

```
beams = "e-", "e+" => circe2 => isr
```

```
$circe2_file = "ilc250.circe"  
$circe2_design = "ILC"  
?circe2_polarized = false
```

```
beams_pol_density = @(-1), @(+1)  
beams_pol_fraction = 100%, 100%
```

```
!! Set  $\alpha(0)$  for ISR splitting  
isr_mass = 0.5109989500E-03 GeV  
isr_alpha = 1/137.035999084
```

```
sqrts = 250 GeV
```

```
integrate (eemumuhh)
```

```
n_events = 10000  
$sample = "eeZH_m10_LR"  
sample_format = stdhep, lcio
```

```
!! Generate events with exclusive ISR photons.  
?isr_handler = true  
$isr_handler_mode = "recoil"
```

```
?keep_remnants = true  
?keep_beams = true  
?hadronization_active = true
```

We generate this final state using an existing 2DHM implementation:

<https://feynrules.irmp.ucl.ac.be/wiki/2HDM>

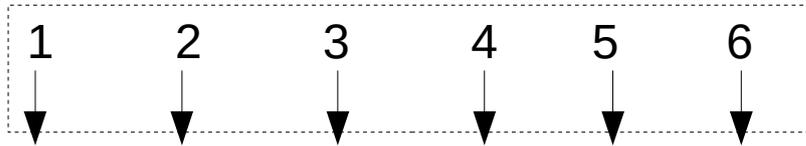
Whizard can interface to UFO model description:

https://feynrules.irmp.ucl.ac.be/raw-attachment/wiki/2HDM/2HDM_UFO.tar.gz

```
model = "2HDM" (ufo)
```

```
!! Show particle content and couplings of '2HDM'  
show (model)
```

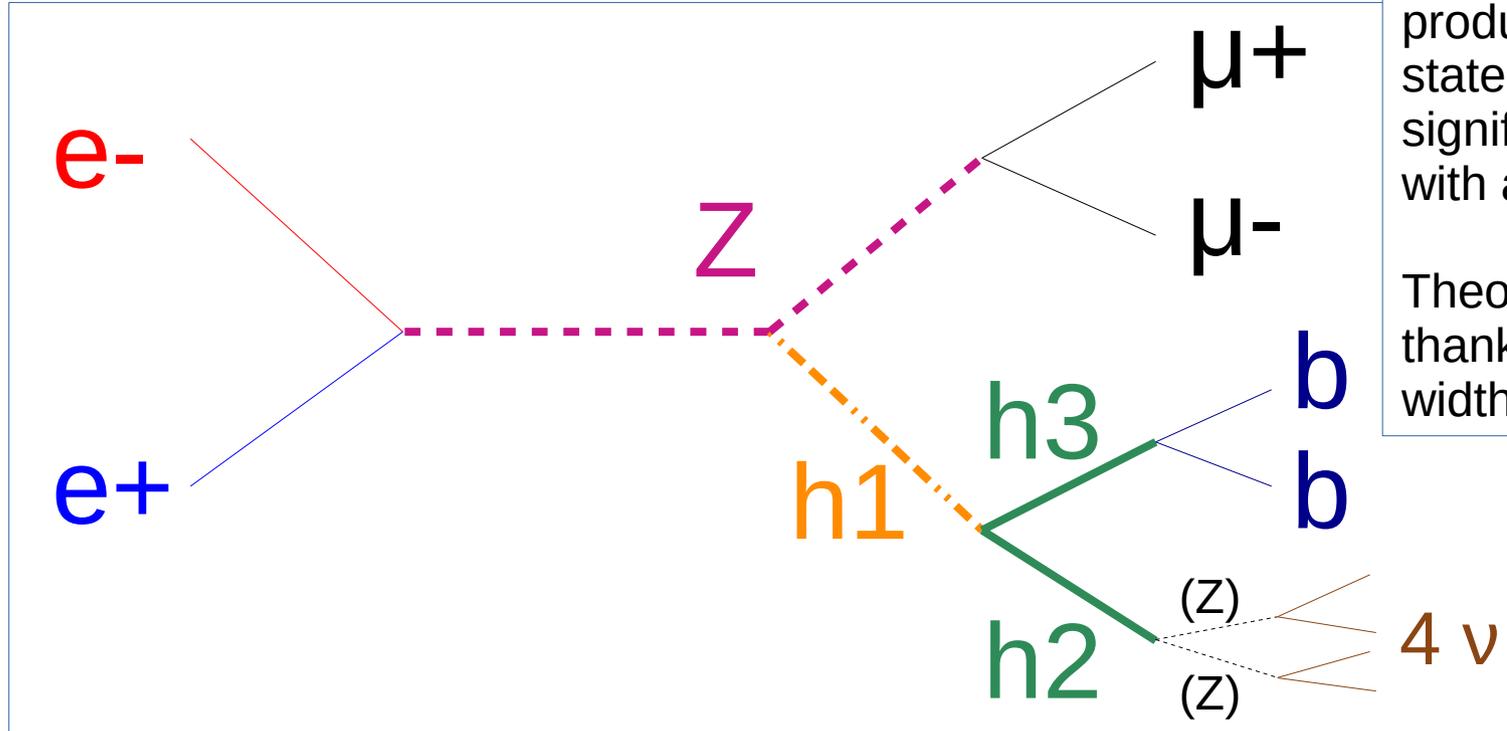
```
mh1 = 125 GeV  
mh2 = 40 GeV  
mh3 = 40 GeV
```



```
process eemumhh = "e-", "e+" => "mu+", "mu-", "h2", "h3" { $restrictions = "3+4~Z && 5+6~h1" }  
process h2dec = h2 => "vm", "vm~", "vt", "vt~"  
process h3dec = h3 => "b", "b~"
```

```
unstable h2(h2dec)  
unstable h3(h3dec)
```

```
?ps_fsr_active = true
```



Hack # 1:

WHIZARD can directly produce full 8-fermion final states, but here it's significantly faster to split up with an intermediate stage.

Theoretically sort of OK here, thanks to narrow higgs boson widths

Hack # 2:

to force the two new scalars to decay in different ways, we pretend they are different particles

```
sample_format = stdhep, lcio
```

```
!! Generate events with exclusive ISR photons.  
?isr_handler = true  
$isr_handler_mode = "recoil"
```

```
?keep_remnants = true  
?keep_beams = true  
?hadronization_active = true
```

```

model = "2HDM" (ufo)

!! Show particle content and couplings of '2HDM'
show (model)

mh1 = 125 GeV
mh2 = 40 GeV
mh3 = 40 GeV

process eemumuhh = "e-", "e+" => "mu+", "mu-", "h2", "h3" { $restrictions = "3+4~Z && 5+6~h1" }
process h2dec = h2 => "vm", "vm~", "vt", "vt~"
process h3dec = h3 => "b", "b~"

unstable h2(h2dec)
unstable h3(h3dec)

?ps_fsr_active = true
?hadronization_active = true
$shower_method = "PYTHIA6"
$ps_PYTHIA_PYGIVE = "MSTJ(28)=2;PMAS(25,1)=2000.0;PMAS(25,2)=10.0;MSTJ(41)=2; MSTU(22)=20; PARJ(21)=0.40000; PARJ(41)=0.11000;
PARJ(42)=0.52000; PARJ(81)=0.25000;PARJ(82)=1.90000; MSTJ(11)=3; PARJ(54)=-0.03100; PARJ(55)=-0.00200;PARJ(1)=0.08500; PARJ(3)=0.45000;
PARJ(4)=0.02500; PARJ(2)=0.31000;PARJ(11)=0.60000; PARJ(12)=0.40000; PARJ(13)=0.72000; PARJ(14)=0.43000;PARJ(15)=0.08000; PARJ(16)=0.08000;
PARJ(17)=0.17000; MSTP(3)=1; MSTP(125)=2; MWID(25)=2"

beams = "e-", "e+" => circe2 => isr

$circe2_file = "ilc250.circe"
$circe2_design = "ILC"
?circe2_polarized = false

beams_pol_density = @(-1), @(+1)
beams_pol_fraction = 100%, 100%

!! Set  $\alpha(0)$  for ISR splitting
isr_mass = 0.5109989500E-03 GeV
isr_alpha = 1/137.035999084

sqrts = 250 GeV

integrate (eemumuhh)

n_events = 10000
$sample = "eeZH_m10_LR"
sample_format = stdhep, lcio

!! Generate events with exclusive ISR photons.
?isr_handler = true
$isr_handler_mode = "recoil"

?keep_remnants = true
?keep_beams = true
?hadronization_active = true

```

use PYTHIA6 for Final State Radiation and hadronisation

The [parameters](#) are the so-called
“OPAL-tune” of hadronization parameters,
determined from LEP data

```
mh1 = 125 GeV
mh2 = 40 GeV
mh3 = 40 GeV
```

```
process eemumuhh = "e-", "e+" => "mu+", "mu-", "h2", "h3" { $restrictions = "3+4~Z && 5+6~h1" }
process h2dec = h2 => "vm", "vm~", "vt", "vt~"
process h3dec = h3 => "b", "b~"
```

```
unstable h2(h2dec)
unstable h3(h3dec)
```

```
?ps_fsr_active = true
?hadronization_active = true
$shower_method = "PYTHIA6"
$ps_PYTHIA_PYGIVE = "MSTJ(28)=2;PMAS(25,1)=2000.0;PMAS(25,2)=10.0;MSTJ(41)=2; MSTU(22)=20; PARJ(21)=0.40000; PARJ(41)=0.11000;
PARJ(42)=0.52000; PARJ(81)=0.25000;PARJ(82)=1.90000; MSTJ(11)=3; PARJ(54)=-0.03100; PARJ(55)=-0.00200;PARJ(1)=0.08500; PARJ(3)=0.45000;
PARJ(4)=0.02500; PARJ(2)=0.31000;PARJ(11)=0.60000; PARJ(12)=0.40000; PARJ(13)=0.72000; PARJ(14)=0.43000;PARJ(15)=0.08000; PARJ(16)=0.08000;
PARJ(17)=0.17000; MSTP(3)=1; MSTP(125)=2; MWID(25)=2"
```

not all collisions will be at exactly 250 GeV

```
beams = "e-", "e+" => circe2 => isr
```

beam energy spectrum (by CIRCE2)
+ Initial State Radiation

```
$circe2_file = "ilc250.circe"
```

ILC250 beam energy spectrum

```
$circe2_design = "ILC"
```

```
?circe2_polarized = false
```

beam polarisation

```
beams_pol_density = @(-1), @(+1)
```

100% left-handed electron

```
beams_pol_fraction = 100%, 100%
```

100% right-handed positron

```
!! Set  $\alpha(0)$  for ISR splitting
```

details for ISR

```
isr_mass = 0.5109989500E-03 GeV
```

```
isr_alpha = 1/137.035999084
```

```
sqrts = 250 GeV
```

nominal center-of-mass energy

```
integrate (eemumuhh)
```

```
n_events = 10000
```

```
$sample = "eeZH_m10_LR"
```

```
sample_format = stdhep, lcio
```

```
!! Generate events with exclusive ISR photons.
```

```
?isr_handler = true
```

simulate ISR with p_T

```
$isr_handler_mode = "recoil"
```

```
?keep_remnants = true
```

```
?keep_beams = true
```

```
?hadronization_active = true
```

```
simulate (eemumuhh)
```

```
model = "2HDM" (ufo)
```

```
!! Show particle content and couplings of '2HDM'  
show (model)
```

```
mh1 = 125 GeV  
mh2 = 40 GeV  
mh3 = 40 GeV
```

```
process eemumuuh = "e-", "e+" => "mu+", "mu-", "h2", "h3" { $restrictions = "3+4~Z && 5+6~h1" }  
process h2dec = h2 => "vm", "vm~", "vt", "vt~"  
process h3dec = h3 => "b", "b~"
```

```
unstable h2(h2dec)  
unstable h3(h3dec)
```

```
?ps_fsr_active = true  
?hadronization_active = true  
$shower_method = "PYTHIA6"  
$ps_PYTHIA_PYGIVE = "MSTJ(28)=2;PMAS(25,1)=2000.0;PMAS(25,2)=10.0;MSTJ(41)=2; MSTU(22)=20; PARJ(21)=0.40000; PARJ(41)=0.11000;  
PARJ(42)=0.52000; PARJ(81)=0.25000;PARJ(82)=1.90000; MSTJ(11)=3; PARJ(54)=-0.03100; PARJ(55)=-0.00200;PARJ(1)=0.08500; PARJ(3)=0.45000;  
PARJ(4)=0.02500; PARJ(2)=0.31000;PARJ(11)=0.60000; PARJ(12)=0.40000; PARJ(13)=0.72000; PARJ(14)=0.43000;PARJ(15)=0.08000; PARJ(16)=0.08000;  
PARJ(17)=0.17000; MSTP(3)=1; MSTP(125)=2; MWID(25)=2"
```

```
beams = "e-", "e+" => circe2 => isr
```

```
$circe2_file = "ilc250.circe"  
$circe2_design = "ILC"  
?circe2_polarized = false
```

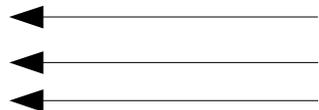
```
beams_pol_density = @(-1), @(+1)  
beams_pol_fraction = 100%, 100%
```

```
!! Set  $\alpha(0)$  for ISR splitting  
isr_mass = 0.5109989500E-03 GeV  
isr_alpha = 1/137.035999084
```

```
sqrt_s = 250 GeV
```

```
integrate (eemumuuh)
```

```
n_events = 10000  
$sample = "eeZH_m10_LR"  
sample_format = stdhep, lcio
```



of events
output filename
output format(s)

```
!! Generate events with exclusive ISR photons.  
?isr_handler = true  
$isr_handler_mode = "recoil"
```

```
?keep_remnants = true  
?keep_beams = true  
?hadronization_active = true
```

```
simulate (eemumuuh)
```



do it!

detailed instructions to (re-)create signal samples [for offline reference]

```
mkdir runWhizard
cd runWhizard

# set up environment for whizard (here on login.snowmass21.io)
source /local-scratch/software/ee_gen/bin/ee_gen_setenv.sh

# get the UFO model for 2HDM model that we'll use
wget https://feynrules.irmp.ucl.ac.be/raw-attachment/wiki/2HDM/2HDM_UFO.tar.gz
tar fvxz ./2HDM_UFO.tar.gz

# run whizard
# (look at the sindarin steering file we've just gone through,
#   adjust parameters such as masses, beam polarization, ...)
whizard my_steering_file.sin

# we've asked events to be output in 2 formats:
#   eeZH_m10_LR.slcio (slcio) & eeZH_m10_LR.hep (stdhep)
# check event #3 from lcio file
dumpevent eeZH_m10_LR.slcio 3
```

```
allin /local-scratch/software/ilc_walkthrough/runWhizard
```

part 2. [Chris]

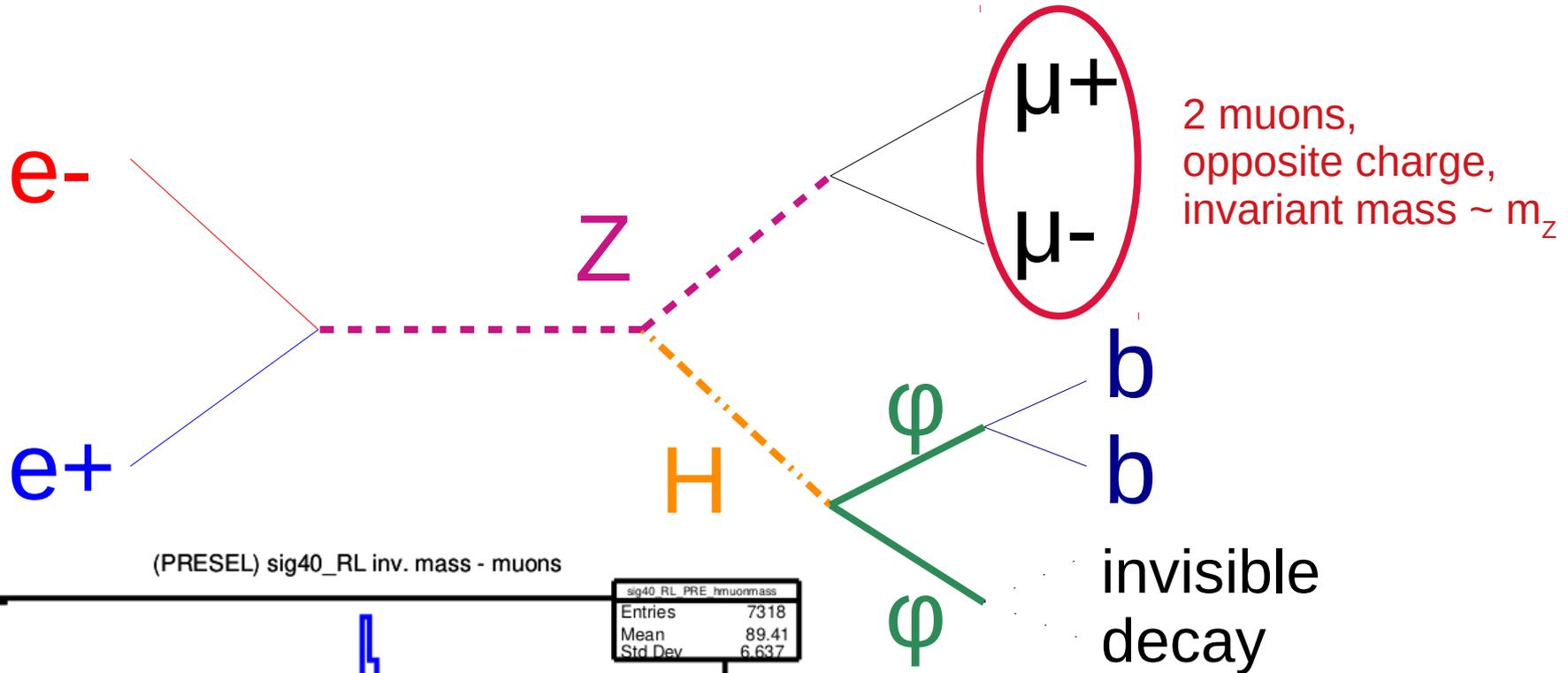
detector simulation using DELPHES

→ miniDST Lcio files

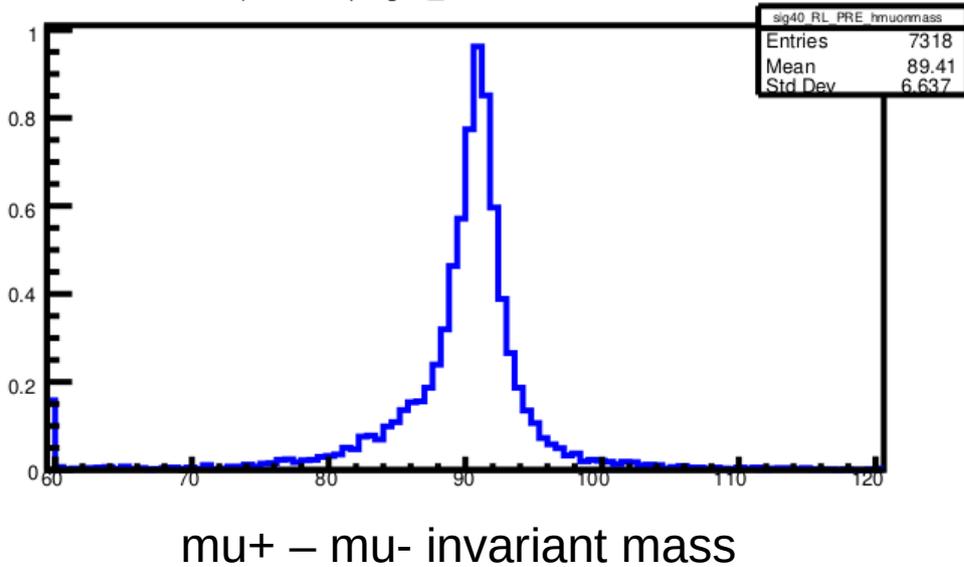
part 3.

a simple analysis to look for this signal

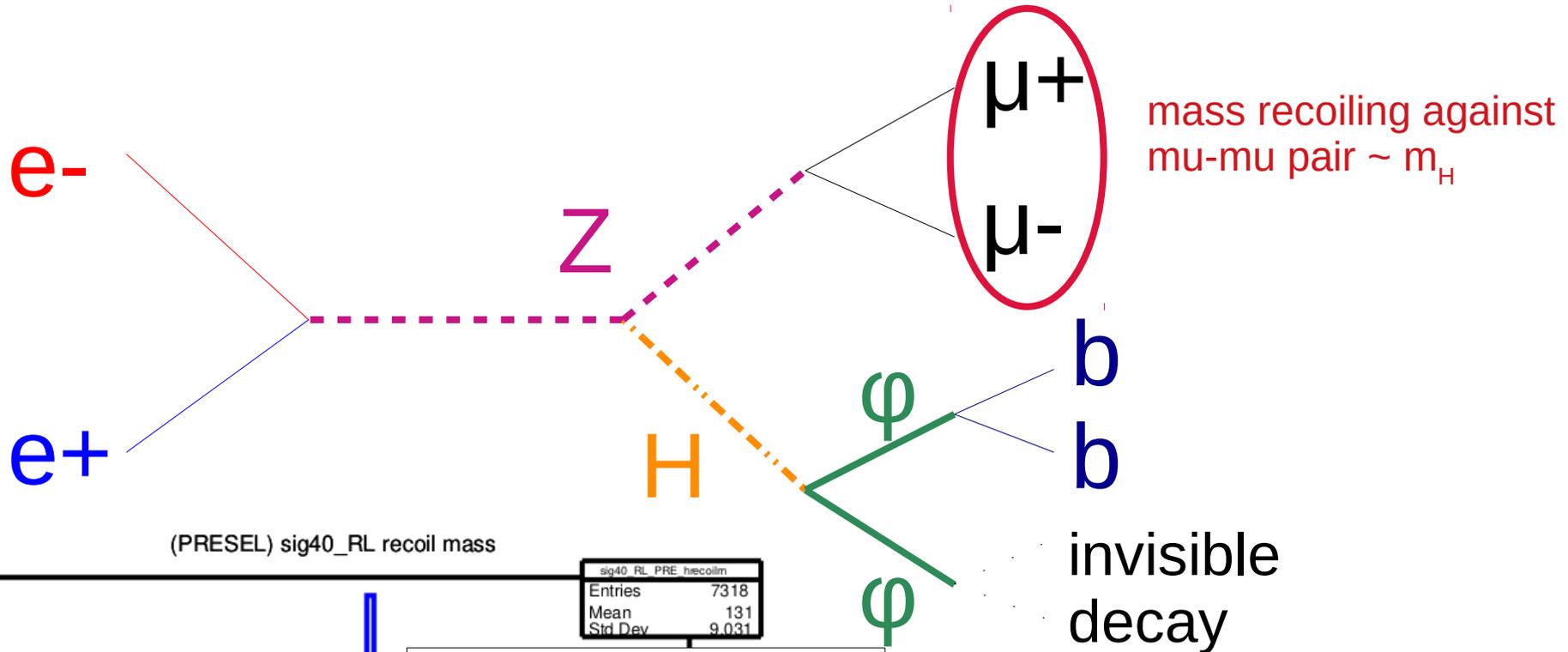
signal properties



(PRESEL) sig40_RL inv. mass - muons



signal properties

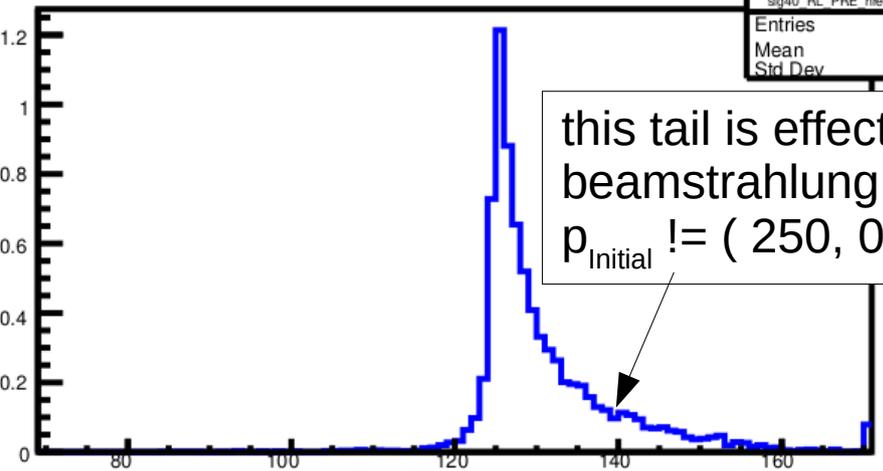


(PRESEL) sig40_RL recoil mass

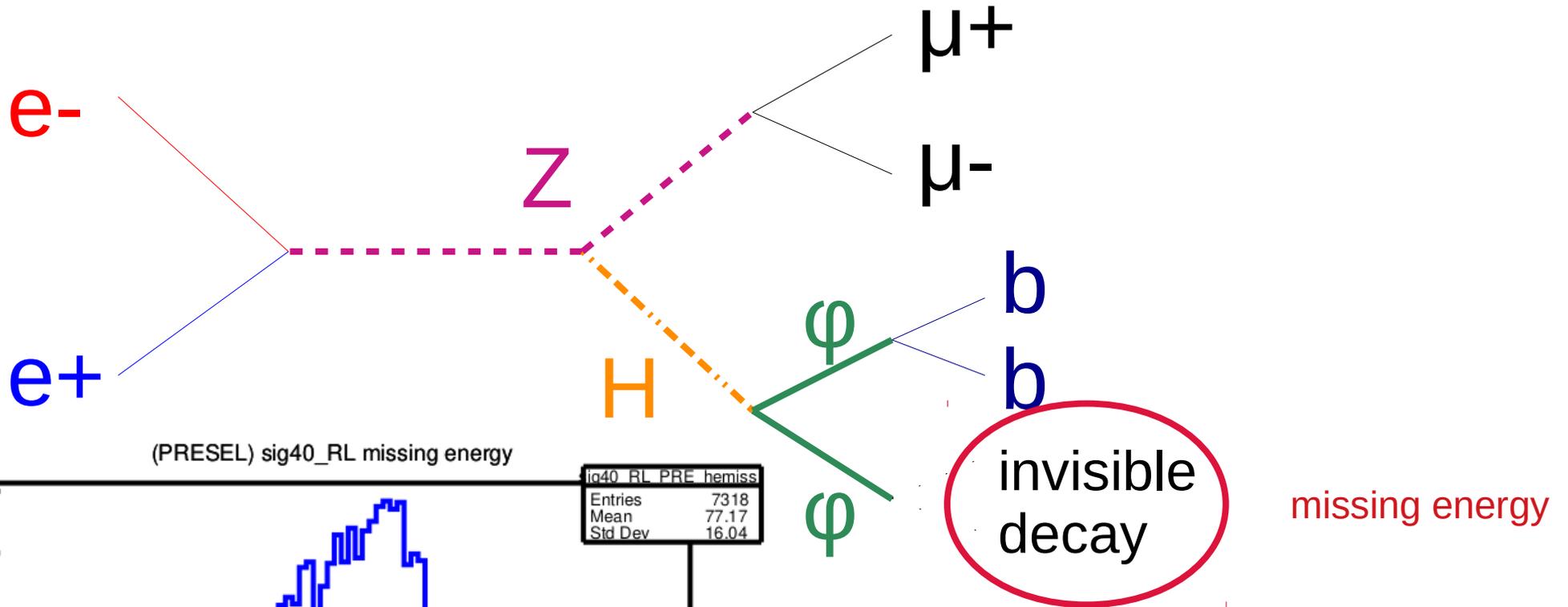
sig40_RL_PRE_hicollm	
Entries	7318
Mean	131
Std Dev	9.031

this tail is effect of beamstrahlung and ISR:
 $p_{\text{Initial}} \neq (250, 0, 0, 0)$

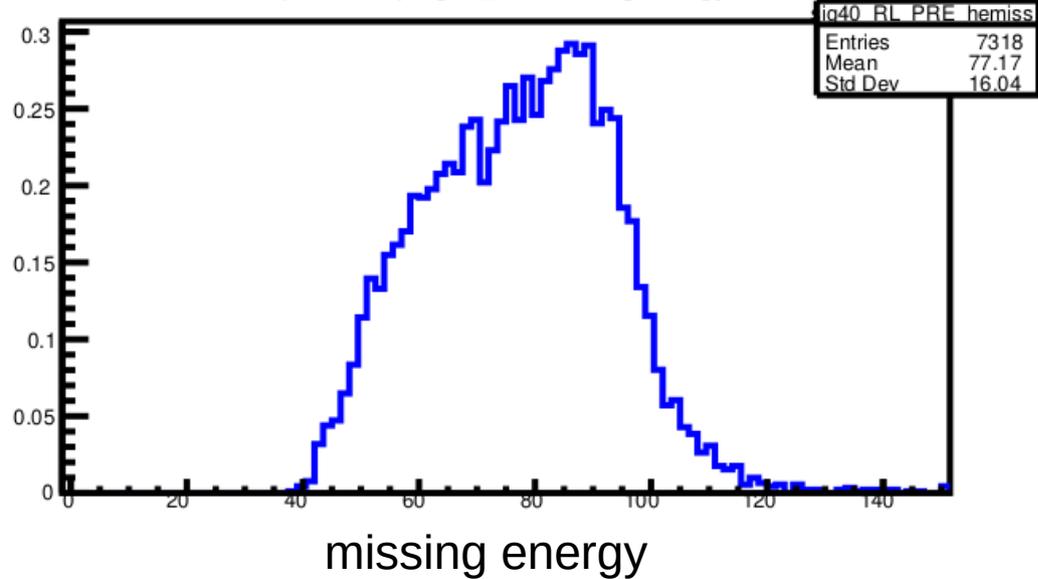
"recoil mass" = $(p_{\text{Initial}} - p_Z) \cdot \text{Mass}()$
 $p_{\text{Initial}} = (250, 0, 0, 0)$



signal properties

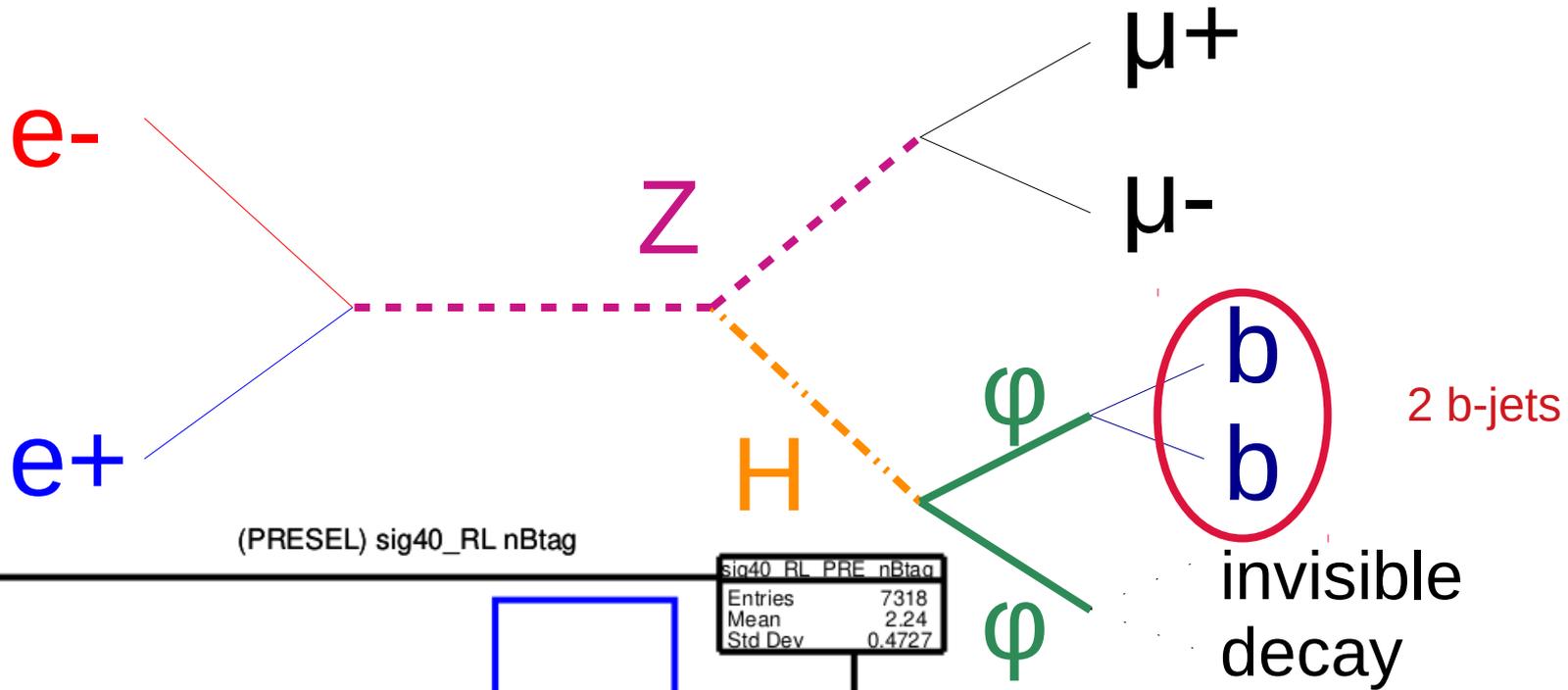


(PRESEL) sig40_RL missing energy



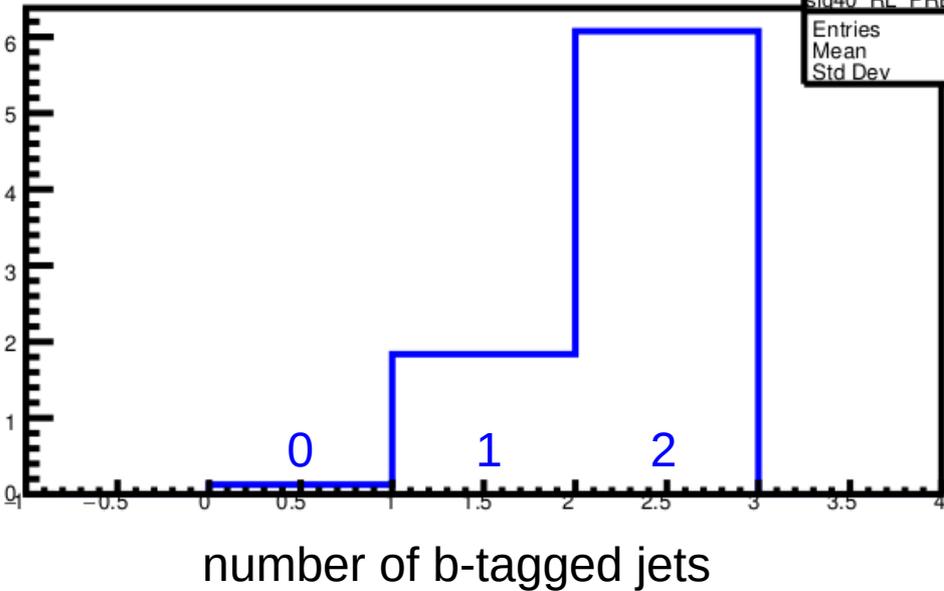
missing energy

signal properties



(PRESEL) sig40_RL nBtag

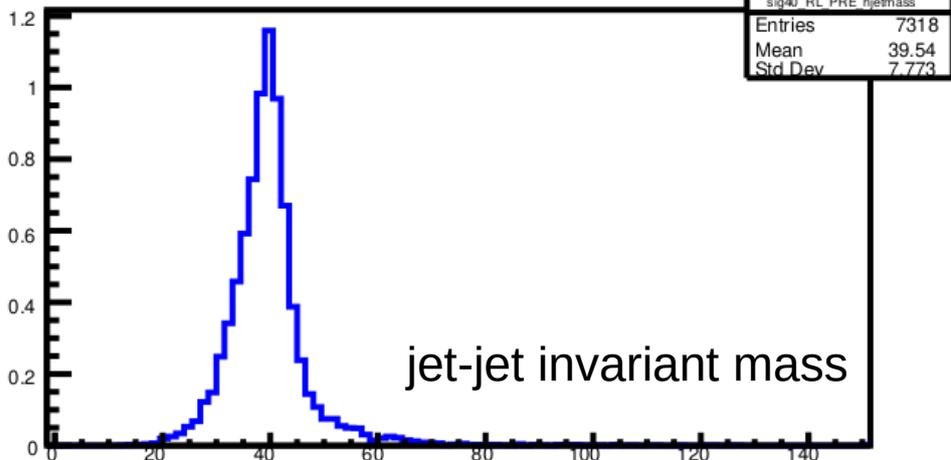
sig40_RL_PRE_nBtag	
Entries	7318
Mean	2.24
Std Dev	0.4727



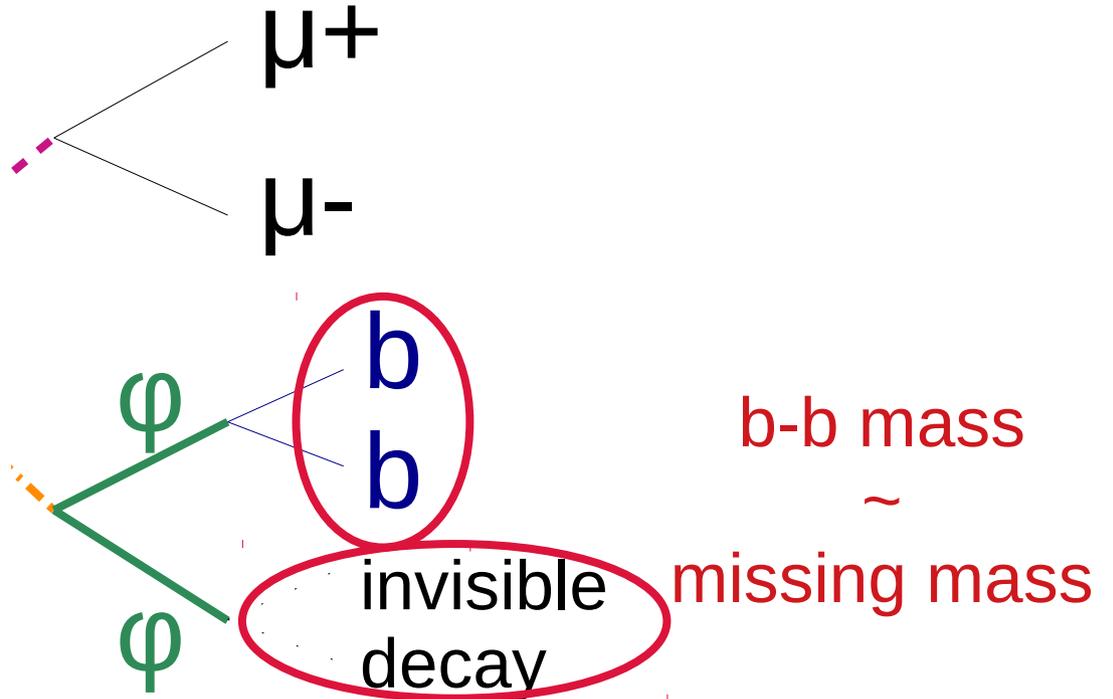
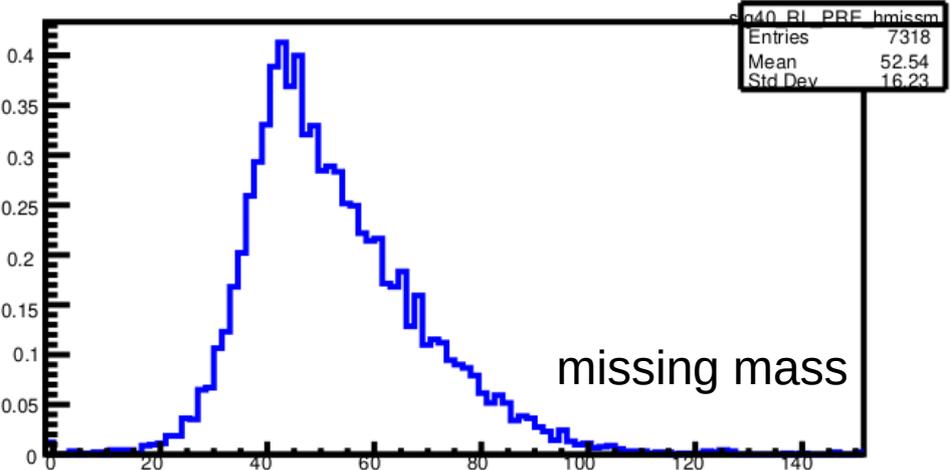
signal properties

$$\text{"missing mass"} = (p_{\text{Initial}} - p_Z - p_{bb}).\text{Mass}()$$

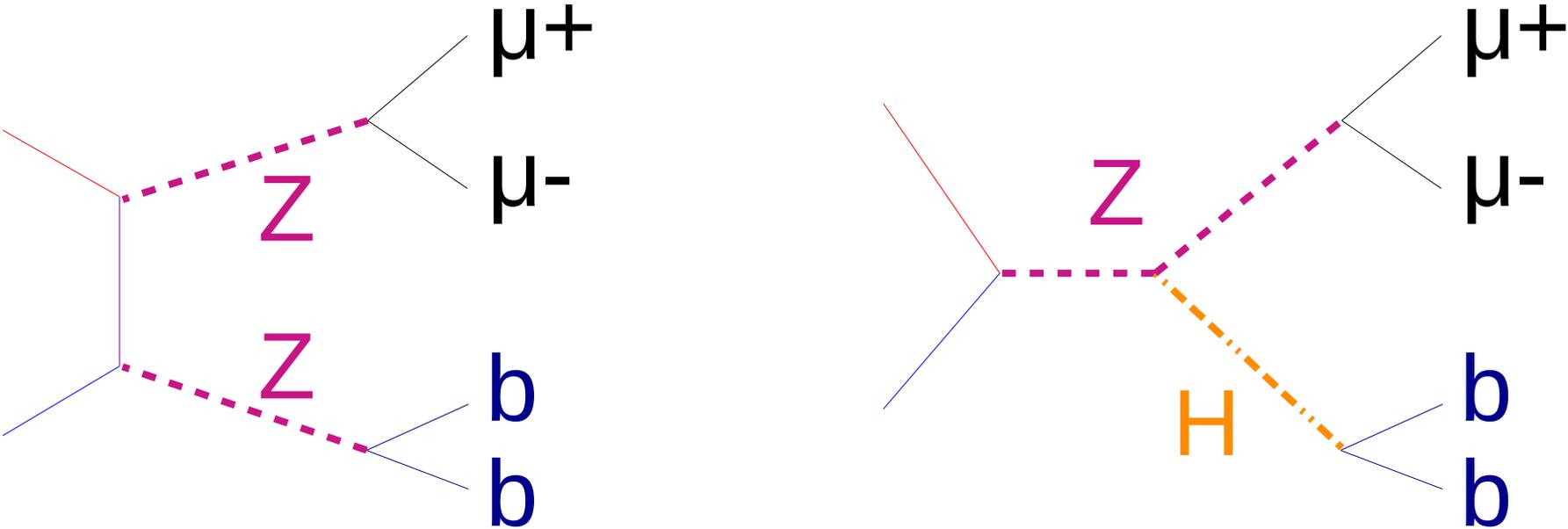
(PRESEL) sig40_RL inv. mass - jets



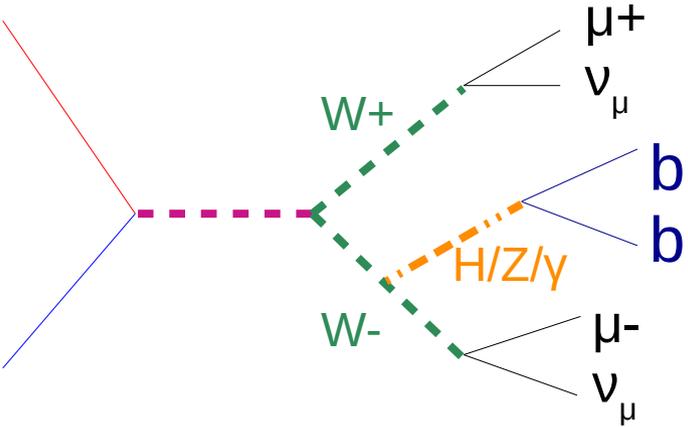
(PRESEL) sig40_RL missing mass



major SM backgrounds



SM 6-f backgrounds have small x-sec at ILC-250: ignore for this exercise



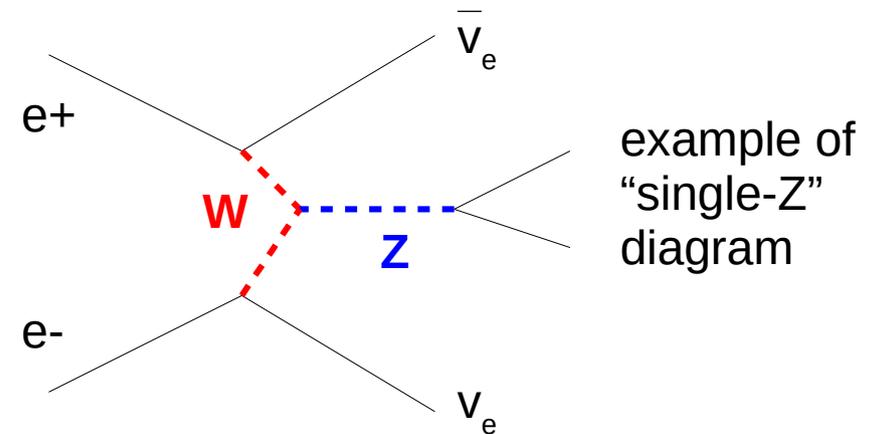
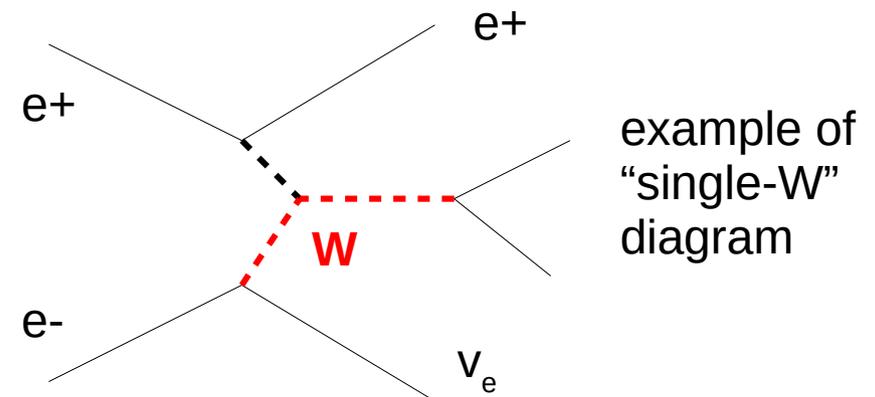
grouping & naming of SM 4-f processes

- all tree-level diagrams contributing to a particular final state are considered
[except Higgs → these are in dedicated samples]
- similar final state combinations are grouped together

in order of priority:

name	final state which could be produced by	example
szeorsw	single-W or single-Z	$e^+ \nu_e e^- \bar{\nu}_e$
sze	single-Z (with e)	$e^+ e^- \mu^+ \mu^-$
sznu	single-Z (with ν_e)	$\mu^+ \nu_e \mu^- \bar{\nu}_e$
sw	single-W	$e^+ \nu_e \mu^- \bar{\nu}_\mu$
zzorww	ZZ or WW	$\mu^- \bar{\nu}_\mu \mu^+ \nu_\mu$
zz	ZZ	$\mu^- \mu^+ \bar{\nu}_\tau \nu_\tau$
ww	WW	$\mu^- \bar{\nu}_\mu \tau^+ \nu_\tau$

- h = fully hadronic = 4 quarks
- l = fully leptonic = 4 leptons
- sl = semi-leptonic = 2 quarks, 2 leptons

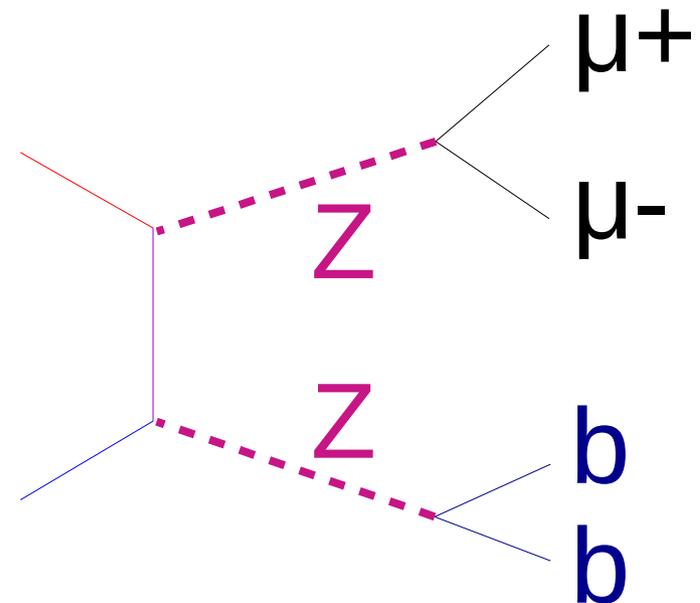


grouping & naming of SM 4-f processes

- all tree-level diagrams contributing to a particular final state
[except Higgs → these are in dedicated samples]
- similar final state combinations are grouped together

name	final state which could be produced by	example
szeorsw	single-W or single-Z	$e^+ \nu_e e^- \bar{\nu}_e$
sze	single-Z (with e)	$e^+ e^- \mu^+ \mu^-$
sznu	single-Z (with ν_e)	$\mu^+ \nu_e \mu^- \bar{\nu}_e$
sw	single-W	$e^+ \nu_e \mu^- \bar{\nu}_\mu$
zzorww	ZZ or WW	$\mu^- \bar{\nu}_\mu \mu^+ \nu_\mu$
zz	ZZ	$\mu^- \mu^+ \bar{\nu}_\tau \nu_\tau$
ww	WW	$\mu^- \bar{\nu}_\mu \tau^+ \nu_\tau$

h = fully hadronic = 4 quarks
l = fully leptonic = 4 leptons
sl = semi-leptonic = 2 quarks, 2 leptons



our major background has 4 fermions
(2-leptons, 2-hadrons)
in “ZZ”-like combination

→ **zz_sl**

location of SM data (DELPHES miniDST)

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/4f/

E250-TDR_ws.P4f_zz_sl.Gwhizard-1_95.eR.pL.I106576.???.stdhep.delphes_card_ILCgen.tcl.slcio
E250-TDR_ws.P4f_zz_sl.Gwhizard-1_95.eL.pR.I106575.???.stdhep.delphes_card_ILCgen.tcl.slcio

CM energy
beam parameters

process name

beam
polarisation

delphes model

also have SM higgs background

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/higgs

E250-TDR_ws.Pe2e2h.Gwhizard-1_95.eL.pR.I106479.001.stdhep.delphes_card_ILCgen.tcl.slcio
E250-TDR_ws.Pe2e2h.Gwhizard-1_95.eR.pL.I106480.001.stdhep.delphes_card_ILCgen.tcl.slcio

“e2e2h” = $\mu^- \mu^+ h$

n.b. many, but not all, samples have zero x-sec for eL.pL and eR.pR

let's get the data

SM background files

on login.snowmass21.io they are already at
[/collab/project/snowmass21/data/ilc/analysis-walkthrough/backgrounds/](http://collab/project/snowmass21/data/ilc/analysis-walkthrough/backgrounds/)

if you are **not** on login.snowmass21.io , download these to a dedicated directory (e.g. `~/snow_walk_data`)

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/4f/E250-TDR_ws.P4f_zz_sl.Gwhizard-1_95.eL.pR.I106575.001.stdhep.delphes_card_ILCgen.tcl.slcio

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/4f/E250-TDR_ws.P4f_zz_sl.Gwhizard-1_95.eL.pR.I106575.002.stdhep.delphes_card_ILCgen.tcl.slcio

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/4f/E250-TDR_ws.P4f_zz_sl.Gwhizard-1_95.eL.pR.I106575.003.stdhep.delphes_card_ILCgen.tcl.slcio

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/4f/E250-TDR_ws.P4f_zz_sl.Gwhizard-1_95.eL.pR.I106575.004.stdhep.delphes_card_ILCgen.tcl.slcio

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/4f/E250-TDR_ws.P4f_zz_sl.Gwhizard-1_95.eL.pR.I106575.004.stdhep.delphes_card_ILCgen.tcl.slcio

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/4f/E250-TDR_ws.P4f_zz_sl.Gwhizard-1_95.eR.pL.I106576.001.stdhep.delphes_card_ILCgen.tcl.slcio

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/4f/E250-TDR_ws.P4f_zz_sl.Gwhizard-1_95.eR.pL.I106576.002.stdhep.delphes_card_ILCgen.tcl.slcio

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/4f/E250-TDR_ws.P4f_zz_sl.Gwhizard-1_95.eR.pL.I106576.003.stdhep.delphes_card_ILCgen.tcl.slcio

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/4f/E250-TDR_ws.P4f_zz_sl.Gwhizard-1_95.eR.pL.I106576.004.stdhep.delphes_card_ILCgen.tcl.slcio

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/4f/E250-TDR_ws.P4f_zz_sl.Gwhizard-1_95.eR.pL.I106576.005.stdhep.delphes_card_ILCgen.tcl.slcio

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/higgs/E250-TDR_ws.Pe2e2h.Gwhizard-1_95.eL.pR.I106479.001.stdhep.delphes_card_ILCgen.tcl.slcio

http://osggridftp02.slac.stanford.edu:8080/sdf/group/lcddata/ilc/user/c/cpotter/mc-dbd/delphes/miniDST/250-TDR_ws/higgs/E250-TDR_ws.Pe2e2h.Gwhizard-1_95.eR.pL.I106480.001.stdhep.delphes_card_ILCgen.tcl.slcio

BSM signal files

on login.snowmass21.io they are at

/collab/project/snowmass21/data/ilc/analysis-walkthrough/signal/miniDST-delphes

otherwise, download from <https://research.kek.jp/people/jeans/snowmassSignal/>

https://research.kek.jp/people/jeans/snowmassSignal/eeZH_m10_LR.delphes.slcio
https://research.kek.jp/people/jeans/snowmassSignal/eeZH_m10_RL.delphes.slcio

$m_\phi = 10 \text{ GeV}$

https://research.kek.jp/people/jeans/snowmassSignal/eeZH_m20_LR.delphes.slcio
https://research.kek.jp/people/jeans/snowmassSignal/eeZH_m20_RL.delphes.slcio

$m_\phi = 20 \text{ GeV}$

https://research.kek.jp/people/jeans/snowmassSignal/eeZH_m30_LR.delphes.slcio
https://research.kek.jp/people/jeans/snowmassSignal/eeZH_m30_RL.delphes.slcio

$m_\phi = 30 \text{ GeV}$

https://research.kek.jp/people/jeans/snowmassSignal/eeZH_m40_LR.delphes.slcio
https://research.kek.jp/people/jeans/snowmassSignal/eeZH_m40_RL.delphes.slcio

$m_\phi = 40 \text{ GeV}$

let's look in one of the signal miniDST files

```
anajob eeZH_m30_RL.delphes.slcio | head -40
```

```
$ anajob eeZH_m30_RL.delphes.slcio | head -40
```

```
.  
. .  
.  
////////////////////////////////////  
EVENT: 1  
RUN: 0  
DETECTOR: unknown  
COLLECTIONS: (see below)  
////////////////////////////////////
```

COLLECTION NAME	COLLECTION TYPE	NUMBER OF ELEMENTS
Durham2Jets	ReconstructedParticle	2
Durham3Jets	ReconstructedParticle	3
Durham4Jets	ReconstructedParticle	4
Durham5Jets	ReconstructedParticle	5
Durham6Jets	ReconstructedParticle	6
IsolatedElectrons	ReconstructedParticle	0
IsolatedMuons	ReconstructedParticle	2
IsolatedPhotons	ReconstructedParticle	1
Jets	ReconstructedParticle	1
MCParticles	MCParticle	95
MCTruthRecoLink	LCRelation	32
PFOs	ReconstructedParticle	32
RecoMCTruthLink	LCRelation	32

MC particles

```
$ anajob eeZH_m30_RL.delphes.slcio | head -40
```

```
.  
. .  
////////////////////////////////////  
EVENT: 1  
RUN: 0  
DETECTOR: unknown  
COLLECTIONS: (see below)  
////////////////////////////////////
```

COLLECTION NAME	COLLECTION TYPE	NUMBER OF ELEMENTS
Durham2Jets	ReconstructedParticle	2
Durham3Jets	ReconstructedParticle	3
Durham4Jets	ReconstructedParticle	4
Durham5Jets	ReconstructedParticle	5
Durham6Jets	ReconstructedParticle	6
IsolatedElectrons	ReconstructedParticle	0
IsolatedMuons	ReconstructedParticle	2
IsolatedPhotons	ReconstructedParticle	1
Jets	ReconstructedParticle	1
MCParticles	MCParticle	95
MCTruthRecoLink	LCRelation	32
PFOs	ReconstructedParticle	32
RecoMCTruthLink	LCRelation	32

reconstructed particles
= Particle Flow Objects
PFOs

```
$ anajob eeZH_m30_RL.delphes.slcio | head -40
```

```
.  
. .  
.  
////////////////////////////////////  
EVENT: 1  
RUN: 0  
DETECTOR: unknown  
COLLECTIONS: (see below)  
////////////////////////////////////
```

COLLECTION NAME	COLLECTION TYPE	NUMBER OF ELEMENTS
Durham2Jets	ReconstructedParticle	2
Durham3Jets	ReconstructedParticle	3
Durham4Jets	ReconstructedParticle	4
Durham5Jets	ReconstructedParticle	5
Durham6Jets	ReconstructedParticle	6
IsolatedElectrons	ReconstructedParticle	0
IsolatedMuons	ReconstructedParticle	2
IsolatedPhotons	ReconstructedParticle	1
Jets	ReconstructedParticle	1
MCParticles	MCParticle	95
MCTruthRecoLink	LCRelation	32
PFOs	ReconstructedParticle	32
RecoMCTruthLink	LCRelation	32

associations between
MC and PFOs
in both directions

```
$ anajob eeZH_m30_RL.delphes.slcio | head -40
```

```
.  
. .  
.  
////////////////////////////////////  
EVENT: 1  
RUN: 0  
DETECTOR: unknown  
COLLECTIONS: (see below)  
////////////////////////////////////
```

COLLECTION NAME	COLLECTION TYPE	NUMBER OF ELEMENTS
Durham2Jets	ReconstructedParticle	2
Durham3Jets	ReconstructedParticle	3
Durham4Jets	ReconstructedParticle	4
Durham5Jets	ReconstructedParticle	5
Durham6Jets	ReconstructedParticle	6
IsolatedElectrons	ReconstructedParticle	0
IsolatedMuons	ReconstructedParticle	2
IsolatedPhotons	ReconstructedParticle	1
Jets	ReconstructedParticle	1
MCParticles	MCParticle	95
MCTruthRecoLink	LCRelation	32
PFOs	ReconstructedParticle	32
RecoMCTruthLink	LCRelation	32

PFOs identified as isolated e, mu, gamma

```
$ anajob eeZH_m30_RL.delphes.slcio | head -40
```

```
.  
. .  
////////////////////////////////////  
EVENT: 1  
RUN: 0  
DETECTOR: unknown  
COLLECTIONS: (see below)  
////////////////////////////////////
```

COLLECTION NAME	COLLECTION TYPE	NUMBER OF ELEMENTS
Durham2Jets	ReconstructedParticle	2
Durham3Jets	ReconstructedParticle	3
Durham4Jets	ReconstructedParticle	4
Durham5Jets	ReconstructedParticle	5
Durham6Jets	ReconstructedParticle	6
IsolatedElectrons	ReconstructedParticle	0
IsolatedMuons	ReconstructedParticle	2
IsolatedPhotons	ReconstructedParticle	1
Jets	ReconstructedParticle	1
MCParticles	MCParticle	95
MCTruthRecoLink	LCRelation	32
PFOs	ReconstructedParticle	32
RecoMCTruthLink	LCRelation	32

remaining PFOs clustered into 2 → 6 jets using Durham algorithm

remaining PFOs clustered by anti- k_T algorithm, $R=1$ and $p_{T\min}=5$ GeV

set up your environment

1. setup ilcsoft:

```
source /cvmfs/ilc.desy.de/sw/x86_64_gcc82_centos7/v02-02/init_ilcsoft.sh
```

(actually, only ROOT and LCIO are needed for this example)

2. change to a new directory

```
mkdir run_walk ; cd run_walk
```

[don't try to run before you can walk]

3. get the example analysis script:

on login.snowmass21.io :

```
cp /local-scratch/software/ilc_walkthrough/tutorial-code/walkthrough_ana.C .
```

otherwise

```
wget https://research.kek.jp/people/jeans/snowmassSignal/walkthrough_ana.C
```

4. create file

```
rootlogon.C
```

with this content:

```
{
  gInterpreter->AddIncludePath("$LCIO");
  gSystem->Load("${LCIO}/lib/liblcio.so");
  gSystem->Load("${LCIO}/lib/liblcioDict.so");
}
```

5. if **not** running on **login.snowmass21.io**
specify the data directory for signal files:
edit these lines in `walkthrough_ana.C`

```
TString inputDir_SIGNAL = "...";  
TString inputDir_BACKGD = "...";
```

6. now let's compile and run the script

```
$ root -b
```

```
-----  
| Welcome to ROOT 6.18/04                               https://root.cern |  
|                                     (c) 1995-2019, The ROOT Team |  
| Built for linuxx8664gcc on Sep 11 2019, 15:38:23 |  
| From tags/v6-18-04@v6-18-04 |  
| Try '.help', '.demo', '.license', '.credits', '.quit'/.q' |  
-----
```

I won't help you if you
don't compile your
(non-trivial) root
macros !

```
root [0] .L walkthrough_ana.C+
```

```
Info in <TUnixSystem::ACLiC>: creating shared library ../../walkthrough_ana_C.so
```

```
root [1] runall(1000)
```

1000=max. events/process
(to speed things up)
default (0) is to use all events

→ creates * plots in `walkthrough.pdf`,
* histograms in `walkthrough.root` and
* selection efficiency tables to `stdout`

let's look at the code in a bit more detail

```
std::vector <TH1F*> analyse_process( TString nickname, std::vector <TString> fnames, int minDstFlavour )
```

- this runs over files / events of a given process,
- gets event information
- calculates kinematic variables (at MC and reconstructed level)
- defines and fills histograms
- applies simple cut-based event selection

```
void runall(int _maxevt=1000) {
```

- specify files for signal and background processes
- calls **analyse_process** for each
- gives appropriate weights to samples (polarisation and integrated luminosity)
- calculates & displays signal efficiencies and backgrounds after selection

accessing MC information

\$ dumpevent SIGNAL_LOCATION/eeZH_m40_LR.delphes.slcio 4 | less

collection name : MCParticles

parameters:

----- print out of MCParticle collection -----

flag: 0x0

simulator status bits: [sbvtcls] s: created in simulation b: backscatter v: vertex is not endpoint of parent t: decayed in tracker c: decayed in calorimeter l: has left detector s: stopped o: ove\
rlay

[id]	index	PDG	px	py	pz	...	energy	gen	...	mass	...	[parents] - [daughters]
[00000073]	0	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[] - [2,3]
[00000074]	1	-11	0.00e+00	0.00e+00	-1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[] - [2,3]
[00000075]	2	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[0,1] - [4,8]
[00000076]	3	-11	0.00e+00	0.00e+00	-1.23e+02	...	1.23e+02	2	...	0.00e+00	...	[0,1] - [5,9]
[00000077]	4	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[2] - [6,7,10,11]
[00000078]	5	-11	0.00e+00	0.00e+00	-1.00e+02	...	1.00e+02	2	...	0.00e+00	...	[3] - [6,7,10,11]
[00000079]	6	35	-3.62e+01	-2.60e+01	1.89e+01	...	6.28e+01	2	...	4.00e+01	...	[4,5] - [12,13,14,15,24]
[00000080]	7	36	2.06e+01	3.00e+01	-3.41e+01	...	6.39e+01	2	...	4.00e+01	...	[4,5] - [16,17]
[00000081]	8	22	0.00e+00	0.00e+00	2.50e-12	...	2.50e-12	1	...	0.00e+00	...	[2] - []
[00000082]	9	22	0.00e+00	0.00e+00	-2.27e+01	...	2.27e+01	1	...	0.00e+00	...	[3] - []
[00000083]	10	-13	5.13e+01	8.37e+00	2.27e+01	...	5.68e+01	2	...	0.00e+00	...	[4,5] - []
[00000084]	11	13	-3.57e+01	-1.24e+01	1.69e+01	...	4.14e+01	2	...	0.00e+00	...	[4,5] - [24]
[00000085]	12	14	6.80e-01	-3.13e+00	1.02e+01	...	1.07e+01	2	...	0.00e+00	...	[6] - [18]
[00000086]	13	-14	-1.02e+01	-9.85e+00	2.65e+00	...	1.44e+01	2	...	0.00e+00	...	[6] - [19]
[00000087]	14	16	-2.49e+01	-1.07e+01	-3.82e+00	...	2.74e+01	2	...	0.00e+00	...	[6] - [20]
[00000088]	15	-16	-1.79e+00	-2.28e+00	9.86e+00	...	1.03e+01	2	...	0.00e+00	...	[6] - [21]
[00000089]	16	5	2.54e+01	3.64e+01	-2.90e+01	...	5.33e+01	2	...	4.70e+00	...	[7] - [22]
[00000090]	17	-5	-4.83e+00	-6.47e+00	-5.11e+00	...	1.07e+01	2	...	4.70e+00	...	[7] - [23]

```
$ dumpevent SIGNAL_LOCATION/eeZH_m40_LR.delphes.slcio 4 | less
```

```
collection name : MCParticles
```

```
parameters:
```

```
----- print out of MCParticle collection -----
```

```
flag: 0x0
```

```
simulator status bits: [sbvtcls] s: created in simulation b: backscatter v: vertex is not endpoint of parent t: decayed in  
tracker c: decayed in calorimeter l: has left detector s: stopped o: ove\  
rlay
```

[id]	index	PDG	px	py	pz	...	energy	gen	...	mass	...	[parents]	-	[daughters]
[00000073]	0	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[]	-	[2,3]
[00000074]	1	-11	0.00e+00	0.00e+00	-1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[]	-	[2,3]
[00000075]	2	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[0,1]	-	[4,8]
[00000076]	3	-11	0.00e+00	0.00e+00	-1.23e+02	...	1.23e+02	2	...	0.00e+00	...	[0,1]	-	[5,9]
[00000077]	4	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[2]	-	[6,7,10,11]
[00000078]	5	-11	0.00e+00	0.00e+00	-1.00e+02	...	1.00e+02	2	...	0.00e+00	...	[3]	-	[6,7,10,11]
[00000079]	6	35	-3.62e+01	-2.60e+01	1.89e+01	...	6.28e+01	2	...	4.00e+01	...	[4,5]	-	[12,13,14,15,24]
[00000080]	7	36	2.06e+01	3.00e+01	-3.41e+01	...	6.39e+01	2	...	4.00e+01	...	[4,5]	-	[16,17]
[00000081]	8	22	0.00e+00	0.00e+00	2.50e-12	...	2.50e-12	1	...	0.00e+00	...	[2]	-	[]
[00000082]	9	22	0.00e+00	0.00e+00	-2.27e+01	...	2.27e+01	1	...	0.00e+00	...	[3]	-	[]
[00000083]	10	-13	5.13e+01	8.37e+00	2.27e+01	...	5.68e+01	2	...	0.00e+00	...	[4,5]	-	[]
[00000084]	11	13	-3.57e+01	-1.24e+01	1.69e+01	...	4.14e+01	2	...	0.00e+00	...	[4,5]	-	[24]
[00000085]	12	14	6.80e-01	-3.13e+00	1.02e+01	...	1.07e+01	2	...	0.00e+00	...	[6]	-	[18]
[00000086]	13	-14	-1.02e+01	-9.85e+00	2.65e+00	...	1.44e+01	2	...	0.00e+00	...	[6]	-	[19]
[00000087]	14	16	-2.49e+01	-1.07e+01	-3.82e+00	...	2.74e+01	2	...	0.00e+00	...	[6]	-	[20]
[00000088]	15	-16	-1.79e+00	-2.28e+00	9.86e+00	...	1.03e+01	2	...	0.00e+00	...	[6]	-	[21]
[00000089]	16	5	2.54e+01	3.64e+01	-2.90e+01	...	5.33e+01	2	...	4.70e+00	...	[7]	-	[22]
[00000090]	17	-5	-4.83e+00	-6.47e+00	-5.11e+00	...	1.07e+01	2	...	4.70e+00	...	[7]	-	[23]

the nominal beam electron & positron

\$ dumpevent SIGNAL_LOCATION/eeZH_m40_LR.delphes.slcio 4 | less

```
collection name : MCParticles
parameters:
```

```
----- print out of MCParticle collection -----
```

```
flag: 0x0
```

```
simulator status bits: [sbvtcls] s: created in simulation b: backscatter v: vertex is not endpoint of parent t: decayed in
tracker c: decayed in calorimeter l: has left detector s: stopped o: ove\
rlay
```

[id]	index	PDG	px,	py,	pz	...	energy	gen	...	mass	...	[parents] - [daughters]
[00000073]	0	11	0.00e+00,	0.00e+00,	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[] - [2,3]
[00000074]	1	-11	0.00e+00,	0.00e+00,	-1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[] - [2,3]
[00000075]	2	11	0.00e+00,	0.00e+00,	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[0,1] - [4,8]
[00000076]	3	-11	0.00e+00,	0.00e+00,	-1.23e+02	...	1.23e+02	2	...	0.00e+00	...	[0,1] - [5,9]
[00000077]	4	11	0.00e+00,	0.00e+00,	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[2] - [6,7,10,11]
[00000078]	5	-11	0.00e+00,	0.00e+00,	-1.00e+02	...	1.00e+02	2	...	0.00e+00	...	[3] - [6,7,10,11]
[00000079]	6	35	-3.62e+01,	-2.60e+01,	1.89e+01	...	6.28e+01	2	...	4.00e+01	...	[4,5] - [12,13,14,15,24]
[00000080]	7	36	2.06e+01,	3.00e+01,	-3.41e+01	...	6.39e+01	2	...	4.00e+01	...	[4,5] - [16,17]
[00000081]	8	22	0.00e+00,	0.00e+00,	2.50e-12	...	2.50e-12	1	...	0.00e+00	...	[2] - []
[00000082]	9	22	0.00e+00,	0.00e+00,	-2.27e+01	...	2.27e+01	1	...	0.00e+00	...	[3] - []
[00000083]	10	-13	5.13e+01,	8.37e+00,	2.27e+01	...	5.68e+01	2	...	0.00e+00	...	[4,5] - []
[00000084]	11	13	-3.57e+01,	-1.24e+01,	1.69e+01	...	4.14e+01	2	...	0.00e+00	...	[4,5] - [24]
[00000085]	12	14	6.80e-01,	-3.13e+00,	1.02e+01	...	1.07e+01	2	...	0.00e+00	...	[6] - [18]
[00000086]	13	-14	-1.02e+01,	-9.85e+00,	2.65e+00	...	1.44e+01	2	...	0.00e+00	...	[6] - [19]
[00000087]	14	16	-2.49e+01,	-1.07e+01,	-3.82e+00	...	2.74e+01	2	...	0.00e+00	...	[6] - [20]
[00000088]	15	-16	-1.79e+00,	-2.28e+00,	9.86e+00	...	1.03e+01	2	...	0.00e+00	...	[6] - [21]
[00000089]	16	5	2.54e+01,	3.64e+01,	-2.90e+01	...	5.33e+01	2	...	4.70e+00	...	[7] - [22]
[00000090]	17	-5	-4.83e+00,	-6.47e+00,	-5.11e+00	...	1.07e+01	2	...	4.70e+00	...	[7] - [23]

the beam electron & positron w/ beam energy spectrum

\$ dumpevent SIGNAL_LOCATION/eeZH_m40_LR.delphes.slcio 4 | less

collection name : MCParticles

parameters:

----- print out of MCParticle collection -----

flag: 0x0

simulator status bits: [sbvtcls] s: created in simulation b: backscatter v: vertex is not endpoint of parent t: decayed in tracker c: decayed in calorimeter l: has left detector s: stopped o: ove\ rlay

[id]	index	PDG	px	py	pz	...	energy	gen	...	mass	...	[parents]	-	[daughters]
[00000073]	0	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[]	-	[2,3]
[00000074]	1	-11	0.00e+00	0.00e+00	-1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[]	-	[2,3]
[00000075]	2	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[0,1]	-	[4,8]
[00000076]	3	-11	0.00e+00	0.00e+00	-1.23e+02	...	1.23e+02	2	...	0.00e+00	...	[0,1]	-	[5,9]
[00000077]	4	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[2]	-	[6,7,10,11]
[00000078]	5	-11	0.00e+00	0.00e+00	-1.00e+02	...	1.00e+02	2	...	0.00e+00	...	[3]	-	[6,7,10,11]
[00000079]	6	35	-3.62e+01	-2.60e+01	1.89e+01	...	6.28e+01	2	...	4.00e+01	...	[4,5]	-	[12,13,14,15,24]
[00000080]	7	36	2.06e+01	3.00e+01	-3.41e+01	...	6.39e+01	2	...	4.00e+01	...	[4,5]	-	[16,17]
[00000081]	8	22	0.00e+00	0.00e+00	2.50e-12	...	2.50e-12	1	...	0.00e+00	...	[2]	-	[]
[00000082]	9	22	0.00e+00	0.00e+00	-2.27e+01	...	2.27e+01	1	...	0.00e+00	...	[3]	-	[]
[00000083]	10	-13	5.13e+01	8.37e+00	2.27e+01	...	5.68e+01	2	...	0.00e+00	...	[4,5]	-	[]
[00000084]	11	13	-3.57e+01	-1.24e+01	1.69e+01	...	4.14e+01	2	...	0.00e+00	...	[4,5]	-	[24]
[00000085]	12	14	6.80e-01	-3.13e+00	1.02e+01	...	1.07e+01	2	...	0.00e+00	...	[6]	-	[18]
[00000086]	13	-14	-1.02e+01	-9.85e+00	2.65e+00	...	1.44e+01	2	...	0.00e+00	...	[6]	-	[19]
[00000087]	14	16	-2.49e+01	-1.07e+01	-3.82e+00	...	2.74e+01	2	...	0.00e+00	...	[6]	-	[20]
[00000088]	15	-16	-1.79e+00	-2.28e+00	9.86e+00	...	1.03e+01	2	...	0.00e+00	...	[6]	-	[21]
[00000089]	16	5	2.54e+01	3.64e+01	-2.90e+01	...	5.33e+01	2	...	4.70e+00	...	[7]	-	[22]
[00000090]	17	-5	-4.83e+00	-6.47e+00	-5.11e+00	...	1.07e+01	2	...	4.70e+00	...	[7]	-	[23]

beam electron & positron after ISR

\$ dumpevent SIGNAL_LOCATION/eeZH_m40_LR.delphes.slcio 4 | less

collection name : MCParticles

parameters:

----- print out of MCParticle collection -----

flag: 0x0

simulator status bits: [sbvtcls] s: created in simulation b: backscatter v: vertex is not endpoint of parent t: decayed in tracker c: decayed in calorimeter l: has left detector s: stopped o: ove\ rlay

[id]	index	PDG	px	py	pz	...	energy	gen	...	mass	...	[parents] - [daughters]
[00000073]	0	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[] - [2,3]
[00000074]	1	-11	0.00e+00	0.00e+00	-1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[] - [2,3]
[00000075]	2	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[0,1] - [4,8]
[00000076]	3	-11	0.00e+00	0.00e+00	-1.23e+02	...	1.23e+02	2	...	0.00e+00	...	[0,1] - [5,9]
[00000077]	4	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[2] - [6,7,10,11]
[00000078]	5	-11	0.00e+00	0.00e+00	-1.00e+02	...	1.00e+02	2	...	0.00e+00	...	[3] - [6,7,10,11]
[00000079]	6	35	-3.62e+01	-2.60e+01	1.89e+01	...	6.28e+01	2	...	4.00e+01	...	[4,5] - [12,13,14,15,24]
[00000080]	7	36	2.06e+01	3.00e+01	-3.41e+01	...	6.39e+01	2	...	4.00e+01	...	[4,5] - [16,17]
[00000081]	8	22	0.00e+00	0.00e+00	2.50e-12	...	2.50e-12	1	...	0.00e+00	...	[2] - []
[00000082]	9	22	0.00e+00	0.00e+00	-2.27e+01	...	2.27e+01	1	...	0.00e+00	...	[3] - []
[00000083]	10	-13	5.13e+01	8.37e+00	2.27e+01	...	5.68e+01	2	...	0.00e+00	...	[4,5] - []
[00000084]	11	13	-3.57e+01	-1.24e+01	1.69e+01	...	4.14e+01	2	...	0.00e+00	...	[4,5] - [24]
[00000085]	12	14	6.80e-01	-3.13e+00	1.02e+01	...	1.07e+01	2	...	0.00e+00	...	[6] - [18]
[00000086]	13	-14	-1.02e+01	-9.85e+00	2.65e+00	...	1.44e+01	2	...	0.00e+00	...	[6] - [19]
[00000087]	14	16	-2.49e+01	-1.07e+01	-3.82e+00	...	2.74e+01	2	...	0.00e+00	...	[6] - [20]
[00000088]	15	-16	-1.79e+00	-2.28e+00	9.86e+00	...	1.03e+01	2	...	0.00e+00	...	[6] - [21]
[00000089]	16	5	2.54e+01	3.64e+01	-2.90e+01	...	5.33e+01	2	...	4.70e+00	...	[7] - [22]
[00000090]	17	-5	-4.83e+00	-6.47e+00	-5.11e+00	...	1.07e+01	2	...	4.70e+00	...	[7] - [23]

the ISR photons

```
$ dumpevent SIGNAL_LOCATION/eeZH_m40_LR.delphes.slcio 4 | less
```

```
collection name : MCParticles
```

```
parameters:
```

```
----- print out of MCParticle collection -----
```

```
flag: 0x0
```

```
simulator status bits: [sbvtcls] s: created in simulation b: backscatter v: vertex is not endpoint of parent t: decayed in  
tracker c: decayed in calorimeter l: has left detector s: stopped o: ove\  
rlay
```

[id]	index	PDG	px	py	pz	...	energy	gen	...	mass	...	[parents]	- [daughters]
[00000073]	0	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[]	- [2,3]
[00000074]	1	-11	0.00e+00	0.00e+00	-1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[]	- [2,3]
[00000075]	2	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[0,1]	- [4,8]
[00000076]	3	-11	0.00e+00	0.00e+00	-1.23e+02	...	1.23e+02	2	...	0.00e+00	...	[0,1]	- [5,9]
[00000077]	4	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[2]	- [6,7,10,11]
[00000078]	5	-11	0.00e+00	0.00e+00	-1.00e+02	...	1.00e+02	2	...	0.00e+00	...	[3]	- [6,7,10,11]
[00000079]	6	35	-3.62e+01	-2.60e+01	1.89e+01	...	6.28e+01	2	...	4.00e+01	...	[4,5]	- [12,13,14,15,24]
[00000080]	7	36	2.06e+01	3.00e+01	-3.41e+01	...	6.39e+01	2	...	4.00e+01	...	[4,5]	- [16,17]
[00000081]	8	22	0.00e+00	0.00e+00	2.50e-12	...	2.50e-12	1	...	0.00e+00	...	[2]	- []
[00000082]	9	22	0.00e+00	0.00e+00	-2.27e+01	...	2.27e+01	1	...	0.00e+00	...	[3]	- []
[00000083]	10	-13	5.13e+01	8.37e+00	2.27e+01	...	5.68e+01	2	...	0.00e+00	...	[4,5]	- []
[00000084]	11	13	-3.57e+01	-1.24e+01	1.69e+01	...	4.14e+01	2	...	0.00e+00	...	[4,5]	- [24]
[00000085]	12	14	6.80e-01	-3.13e+00	1.02e+01	...	1.07e+01	2	...	0.00e+00	...	[6]	- [18]
[00000086]	13	-14	-1.02e+01	-9.85e+00	2.65e+00	...	1.44e+01	2	...	0.00e+00	...	[6]	- [19]
[00000087]	14	16	-2.49e+01	-1.07e+01	-3.82e+00	...	2.74e+01	2	...	0.00e+00	...	[6]	- [20]
[00000088]	15	-16	-1.79e+00	-2.28e+00	9.86e+00	...	1.03e+01	2	...	0.00e+00	...	[6]	- [21]
[00000089]	16	5	2.54e+01	3.64e+01	-2.90e+01	...	5.33e+01	2	...	4.70e+00	...	[7]	- [22]
[00000090]	17	-5	-4.83e+00	-6.47e+00	-5.11e+00	...	1.07e+01	2	...	4.70e+00	...	[7]	- [23]

the two muons

\$ dumpevent SIGNAL_LOCATION/eeZH_m40_LR.delphes.slcio 4 | less

collection name : MCParticles

parameters:

----- print out of MCParticle collection -----

flag: 0x0

simulator status bits: [sbvtcls] s: created in simulation b: backscatter v: vertex is not endpoint of parent t: decayed in tracker c: decayed in calorimeter l: has left detector s: stopped o: ove\ rlay

[id]	index	PDG	px	py	pz	...	energy	gen	...	mass	...	[parents] - [daughters]
[00000073]	0	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[] - [2,3]
[00000074]	1	-11	0.00e+00	0.00e+00	-1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[] - [2,3]
[00000075]	2	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[0,1] - [4,8]
[00000076]	3	-11	0.00e+00	0.00e+00	-1.23e+02	...	1.23e+02	2	...	0.00e+00	...	[0,1] - [5,9]
[00000077]	4	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[2] - [6,7,10,11]
[00000078]	5	-11	0.00e+00	0.00e+00	-1.00e+02	...	1.00e+02	2	...	0.00e+00	...	[3] - [6,7,10,11]
[00000079]	6	35	-3.62e+01	-2.60e+01	1.89e+01	...	6.28e+01	2	...	4.00e+01	...	[4,5] - [12,13,14,15,24]
[00000080]	7	36	2.06e+01	3.00e+01	-3.41e+01	...	6.39e+01	2	...	4.00e+01	...	[4,5] - [16,17]
[00000081]	8	22	0.00e+00	0.00e+00	2.50e-12	...	2.50e-12	1	...	0.00e+00	...	[2] - []
[00000082]	9	22	0.00e+00	0.00e+00	-2.27e+01	...	2.27e+01	1	...	0.00e+00	...	[3] - []
[00000083]	10	-13	5.13e+01	8.37e+00	2.27e+01	...	5.68e+01	2	...	0.00e+00	...	[4,5] - []
[00000084]	11	13	-3.57e+01	-1.24e+01	1.69e+01	...	4.14e+01	2	...	0.00e+00	...	[4,5] - [24]
[00000085]	12	14	6.80e-01	-3.13e+00	1.02e+01	...	1.07e+01	2	...	0.00e+00	...	[6] - [18]
[00000086]	13	-14	-1.02e+01	-9.85e+00	2.65e+00	...	1.44e+01	2	...	0.00e+00	...	[6] - [19]
[00000087]	14	16	-2.49e+01	-1.07e+01	-3.82e+00	...	2.74e+01	2	...	0.00e+00	...	[6] - [20]
[00000088]	15	-16	-1.79e+00	-2.28e+00	9.86e+00	...	1.03e+01	2	...	0.00e+00	...	[6] - [21]
[00000089]	16	5	2.54e+01	3.64e+01	-2.90e+01	...	5.33e+01	2	...	4.70e+00	...	[7] - [22]
[00000090]	17	-5	-4.83e+00	-6.47e+00	-5.11e+00	...	1.07e+01	2	...	4.70e+00	...	[7] - [23]

the neutrinos from the invisible new scalar decay

```
$ dumpevent SIGNAL_LOCATION/eeZH_m40_LR.delphes.slcio 4 | less
```

```
collection name : MCParticles
```

```
parameters:
```

```
----- print out of MCParticle collection -----
```

```
flag: 0x0
```

```
simulator status bits: [sbvtcls] s: created in simulation b: backscatter v: vertex is not endpoint of parent t: decayed in  
tracker c: decayed in calorimeter l: has left detector s: stopped o: ove\  
rlay
```

[id]	index	PDG	px	py	pz	...	energy	gen	...	mass	...	[parents]	-	[daughters]
[00000073]	0	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[]	-	[2,3]
[00000074]	1	-11	0.00e+00	0.00e+00	-1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[]	-	[2,3]
[00000075]	2	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[0,1]	-	[4,8]
[00000076]	3	-11	0.00e+00	0.00e+00	-1.23e+02	...	1.23e+02	2	...	0.00e+00	...	[0,1]	-	[5,9]
[00000077]	4	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[2]	-	[6,7,10,11]
[00000078]	5	-11	0.00e+00	0.00e+00	-1.00e+02	...	1.00e+02	2	...	0.00e+00	...	[3]	-	[6,7,10,11]
[00000079]	6	35	-3.62e+01	-2.60e+01	1.89e+01	...	6.28e+01	2	...	4.00e+01	...	[4,5]	-	[12,13,14,15,24]
[00000080]	7	36	2.06e+01	3.00e+01	-3.41e+01	...	6.39e+01	2	...	4.00e+01	...	[4,5]	-	[16,17]
[00000081]	8	22	0.00e+00	0.00e+00	2.50e-12	...	2.50e-12	1	...	0.00e+00	...	[2]	-	[]
[00000082]	9	22	0.00e+00	0.00e+00	-2.27e+01	...	2.27e+01	1	...	0.00e+00	...	[3]	-	[]
[00000083]	10	-13	5.13e+01	8.37e+00	2.27e+01	...	5.68e+01	2	...	0.00e+00	...	[4,5]	-	[]
[00000084]	11	13	-3.57e+01	-1.24e+01	1.69e+01	...	4.14e+01	2	...	0.00e+00	...	[4,5]	-	[24]
[00000085]	12	14	6.80e-01	-3.13e+00	1.02e+01	...	1.07e+01	2	...	0.00e+00	...	[6]	-	[18]
[00000086]	13	-14	-1.02e+01	-9.85e+00	2.65e+00	...	1.44e+01	2	...	0.00e+00	...	[6]	-	[19]
[00000087]	14	16	-2.49e+01	-1.07e+01	-3.82e+00	...	2.74e+01	2	...	0.00e+00	...	[6]	-	[20]
[00000088]	15	-16	-1.79e+00	-2.28e+00	9.86e+00	...	1.03e+01	2	...	0.00e+00	...	[6]	-	[21]
[00000089]	16	5	2.54e+01	3.64e+01	-2.90e+01	...	5.33e+01	2	...	4.70e+00	...	[7]	-	[22]
[00000090]	17	-5	-4.83e+00	-6.47e+00	-5.11e+00	...	1.07e+01	2	...	4.70e+00	...	[7]	-	[23]

the b quarks from the other scalar decay

\$ dumpevent SIGNAL_LOCATION/eeZH_m40_LR.delphes.slcio 4 | less

```
collection name : MCParticles
parameters:
```

```
----- print out of MCParticle collection -----
```

```
flag: 0x0
```

```
simulator status bits: [sbvtcls] s: created in simulation b: backscatter v: vertex is not endpoint of parent t: decayed in
tracker c: decayed in calorimeter l: has left detector s: stopped o: ove\
rlay
```

[id]	index	PDG	px	py	pz	...	energy	gen	...	mass	...	[parents] - [daughters]
[00000073]	0	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[] - [2,3]
[00000074]	1	-11	0.00e+00	0.00e+00	-1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[] - [2,3]
[00000075]	2	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[0,1] - [4,8]
[00000076]	3	-11	0.00e+00	0.00e+00	-1.23e+02	...	1.23e+02	2	...	0.00e+00	...	[0,1] - [5,9]
[00000077]	4	11	0.00e+00	0.00e+00	1.25e+02	...	1.25e+02	2	...	0.00e+00	...	[2] - [6,7,10,11]
[00000078]	5	-11	0.00e+00	0.00e+00	-1.00e+02	...	1.00e+02	2	...	0.00e+00	...	[3] - [6,7,10,11]
[00000079]	6	35	-3.62e+01	-2.60e+01	1.89e+01	...	6.28e+01	2	...	4.00e+01	...	[4,5] - [12,13,14,15,24]
[00000080]	7	36	2.06e+01	3.00e+01	-3.41e+01	...	6.39e+01	2	...	4.00e+01	...	[4,5] - [16,17]
[00000081]	8	22	0.00e+00	0.00e+00	2.50e-12	...	2.50e-12	1	...	0.00e+00	...	[2] - []
[00000082]	9	22	0.00e+00	0.00e+00	-2.27e+01	...	2.27e+01	1	...	0.00e+00	...	[3] - []
[00000083]	10	-13	5.13e+01	8.37e+00	2.27e+01	...	5.68e+01	2	...	0.00e+00	...	[4,5] - []
[00000084]	11	13	-3.57e+01	-1.24e+01	1.69e+01	...	4.14e+01	2	...	0.00e+00	...	[4,5] - [24]
[00000085]	12	14	6.80e-01	-3.13e+00	1.02e+01	...	1.07e+01	2	...	0.00e+00	...	[6] - [18]
[00000086]	13	-14	-1.02e+01	-9.85e+00	2.65e+00	...	1.44e+01	2	...	0.00e+00	...	[6] - [19]
[00000087]	14	16	-2.49e+01	-1.07e+01	-3.82e+00	...	2.74e+01	2	...	0.00e+00	...	[6] - [20]
[00000088]	15	-16	-1.79e+00	-2.28e+00	9.86e+00	...	1.03e+01	2	...	0.00e+00	...	[6] - [21]
[00000089]	16	5	2.54e+01	3.64e+01	-2.90e+01	...	5.33e+01	2	...	4.70e+00	...	[7] - [22]
[00000090]	17	-5	-4.83e+00	-6.47e+00	-5.11e+00	...	1.07e+01	2	...	4.70e+00	...	[7] - [23]

the detected particles

walkthrough_ana.C

```
mcpColName="MCParticles";
. . . .
//-----
// first look at some MC-level information
//-----
LCIterator<MCParticle> mcps( evt, mcpColName ) ;

// find the initial mu+- and b/b-bar in the event listing
MCParticle* MCmuplus(0);
MCParticle* MCmuminus(0);
MCParticle* MCb(0);
MCParticle* MCbbar(0);
auto mcp = mcps.next();
while ( mcp ) {
    switch ( mcp->getPDG() ) {
        case 13:
            if ( !MCmuminus ) MCmuminus=mcp;
            break;
        case -13:
            if ( !MCmuplus ) MCmuplus=mcp;
            break;
        case 5:
            if ( !MCb ) MCb=mcp;
            break;
        case -5:
            if ( !MCbbar ) MCbbar=mcp;
            break;
        default:
            break;
    }
    mcp = mcps.next();
}
. . . .
const auto& vMCmuminus = v4( MCmuminus );
```

reconstructed information

the muons

```
std::string muoColName = "IsolatedMuons";

    LCIterator<ReconstructedParticle> muons( evt, muoColName ) ;

. . .

    if( jets.size() == 2 && muons.size() == 2 ) {

        auto mu1 = muons.next();
        auto mu2 = muons.next();

. . .

        // TLorentzVectors for the objects
        const auto& vm1 = v4(mu1) ;
        const auto& vm2 = v4(mu2) ;
```

beware: names of collections are often different in delphes/SGV/fullsim-miniDST

the jets

```
jetColName="Durham2Jets";

LCIterator<ReconstructedParticle> jets( evt, jetColName ) ;

if( jets.size() == 2 && muons.size() == 2 ) {

auto j1 = jets.next();
auto j2 = jets.next();

const auto& vj1 = v4Jet(j1) ;
const auto& vj2 = v4Jet(j2) ;

int j1_nch(0);
for ( size_t i=0; i<j1->getParticles().size(); i++) {
    if ( j1->getParticles()[i]->getCharge()!=0 ) j1_nch++;
}
```

* there is a bug in the current delphes2LCIO,
which can give rise to neutral hadrons with $E < M$ (just been fixed, samples will be re-created)

v4Jet() contains an approximate work-around

b-tag information

```
pidName="JetParameters";

// particle ID handler for the jets (eg to get b-tag information)
PIDHandler *pidh = new PIDHandler( evt->getCollection( jetColName ) );
int ilcfi = pidh->getAlgorithmID( pidName );
int ibtag = pidh->getParameterIndex(ilcfi, "BTag");

// btag information for the two jets
float flvtag1 = pidh->getParticleID(j1, ilcfi).getParameters()[ibtag];
float flvtag2 = pidh->getParticleID(j2, ilcfi).getParameters()[ibtag];
if ( minDstFlavour==0 ) { // delphes
    // this is how to get other b/c-tag info from the jets (DELPHES)
    // int btag1_90 = (flvtag1 & ( 1 << 0 )) >> 0; // btag hiEff 90% eff
    // int btag1_70 = (flvtag1 & ( 1 << 1 )) >> 1; // btag medEff 70% eff
    // int btag1_50 = (flvtag1 & ( 1 << 2 )) >> 2; // btag hiPur 50% eff
    // int ctag1_55 = (flvtag1 & ( 1 << 3 )) >> 3; // ctag hiEff 55% eff
    // int ctag1_30 = (flvtag1 & ( 1 << 4 )) >> 4; // ctag medEff 30% eff
    // int ctag1_20 = (flvtag1 & ( 1 << 5 )) >> 5; // ctag hiPur 20% eff
    btag1 = ( int(flvtag1) & ( 1 << 0 )) >> 0;
    btag2 = ( int(flvtag2) & ( 1 << 0 )) >> 0;
} else if ( minDstFlavour==1 ) { // SGV, cut on lcfi btag output
    btag1 = int(flvtag1>0.7); // user-defined cut on b-tag score
    btag2 = int(flvtag2>0.7);
}
}
```

```
$ dumpevent SIGNAL_LOCATION/eeZH_m40_LR.delphes.slcio 4 | less
```

```
collection name : Durham2Jets
parameters:
```

```
----- print out of ReconstructedParticle collection -----
```

```
flag: 0x0
parameter PIDAlgorithmTypeID [int]: 0,
parameter ExclYflip12_78 [float]: 0, 0.0026713, 0.000272677, 0.000215444, 0.000209659, 0, 0,
parameter PIDAlgorithmTypeName [string]: JetParameters,
parameter ParameterNames_JetParameters [string]: Flavor, FlavorAlgo, FlavorPhys, BTag, BTagAlgo,
BTagPhys, TauTag, Charge, EhadOverEem,
```

links between reconstructed and MC particles

- which MC particle(s) produced the hits included in this reconstructed particle?
- to which reconstructed particle(s) were the hits induced by this MC particle assigned ?

RecoMCTruthLink	LCRelation
MCTruthRecoLink	LCRelation

```
// links from reco -> MC particles
LCCollection* linkcol = evt->getCollection( "RecoMCTruthLink" );
LCRelationNavigator reco_mc_Navi( linkcol );

cout << "number of MC particles linked to the isolated muon PFO = " <<
      reco_mc_Navi.getRelatedToObjects(mu1).size() << endl;

for (size_t k=0; k<reco_mc_Navi.getRelatedToObjects(mu1).size(); k++) {
  cout << k << " " << reco_mc_Navi.getRelatedToObjects(mu1)[k] << endl;
  if ( reco_mc_Navi.getRelatedToObjects(mu1)[k] ) {
    MCParticle* mcp = dynamic_cast <MCParticle*> (reco_mc_Navi.getRelatedToObjects(mu1)[k]);
    // weight of the connection; this is a combination of "track" and "cluster" weights
    float wgt = reco_mc_Navi.getRelatedToWeights(mu1)[k];
    // decomposed into track weight
    // (what fraction of tracker hits in this PFO were created by this particle)
    float trackwgt = (int(wgt)%10000)/1000.;
    // similar, for calorimeter hit energies
    float clusterwgt = (int(wgt)/10000)/1000. ;
  }
}
```

[probably mostly useful for full-simulation studies,
in which reconstruction can get it wrong on a hit-level]

look at walkthrough.pdf file you created

look at walkthrough.pdf file you created

4 pages, one per polarisation combination $-+$, $+ -$, $++$, $--$

Interlude 2: Why these funny values?

- The ILC Strawman Running Scenario & Polarisation



- beam polarisation absolute values:

- Electron beam: $|P(e^-)| \geq 80\%$
- Positron beam: $|P(e^+)| = 30\%$,
at 500 GeV upgradable to 60%
at 1 TeV assume 20%

- Notation: ($P(e^-)$, $P(e^+)$)**

- sharing of luminosity between polarisation signs:

all up-to-date numbers
in ILC input document
to the European strategy

\sqrt{s}	$\int \mathcal{L} dt$	$--$	$+ -$	$++$	$--$
250 GeV	2 ab ⁻¹	0.9 ab ⁻¹	0.9 ab ⁻¹	0.1 ab ⁻¹	0.1 ab ⁻¹
350 GeV	200 fb ⁻¹	135 fb ⁻¹	45 fb ⁻¹	10 fb ⁻¹	10 fb ⁻¹
500 GeV	4 ab ⁻¹	1.6 ab ⁻¹	1.6 ab ⁻¹	0.4 ab ⁻¹	0.4 ab ⁻¹
1 TeV	8 ab ⁻¹	3.2 ab ⁻¹	3.2 ab ⁻¹	0.8 ab ⁻¹	0.8 ab ⁻¹
91 GeV	100 fb ⁻¹	40 fb ⁻¹	40 fb ⁻¹	10 fb ⁻¹	10 fb ⁻¹
161 GeV	500 fb ⁻¹	340 fb ⁻¹	110 fb ⁻¹	25 fb ⁻¹	25 fb ⁻¹

detailed reasoning c.f.
[arXiv:1506.07830](https://arxiv.org/abs/1506.07830)

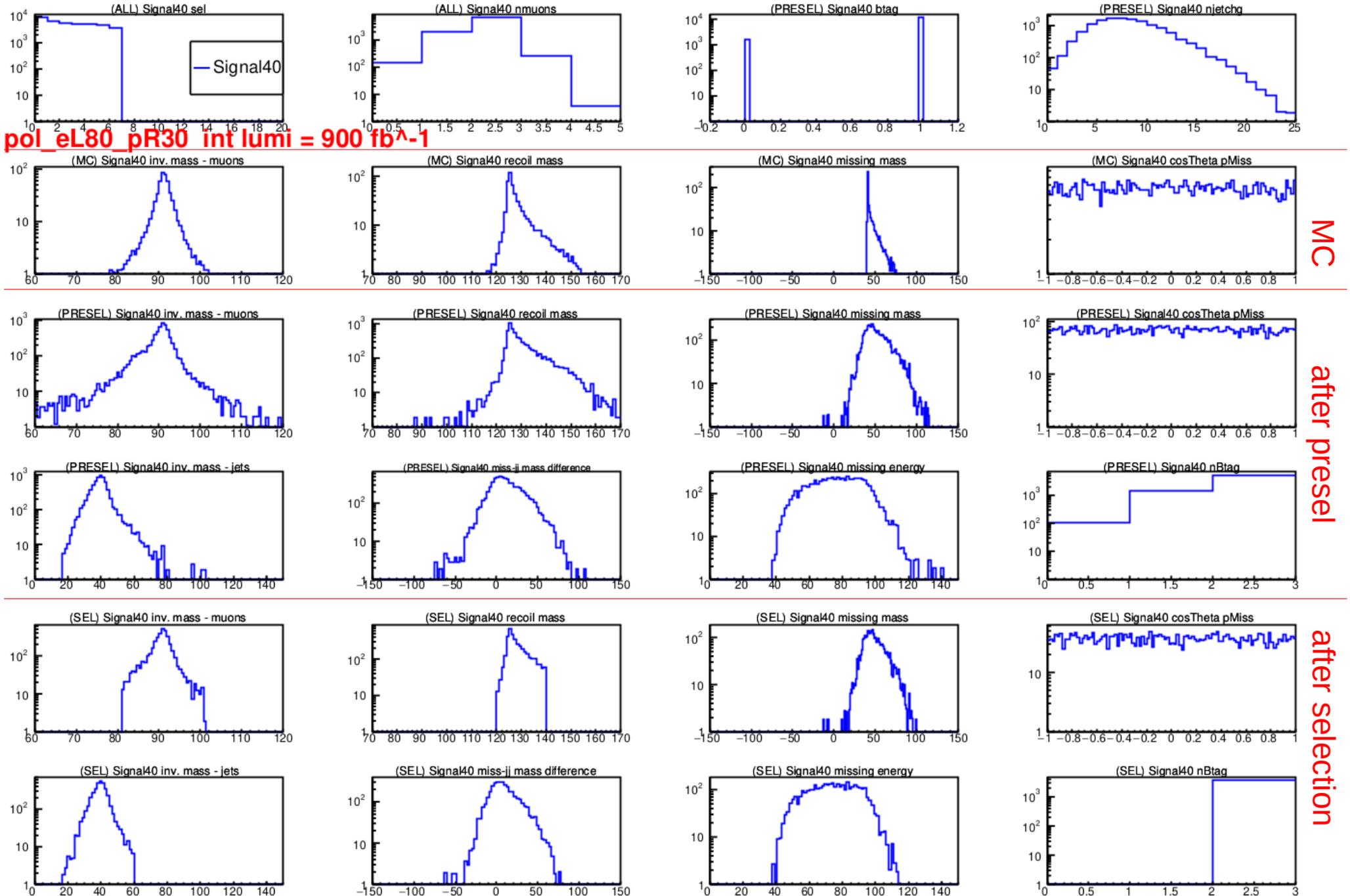
J. List

these are essentially 4 statistically independent experiments

collection of all the histograms we defined

BSM signal (m=40 GeV)

normalised assuming that $\sigma_{\text{BSM}} = \sigma_{\text{SM}}$

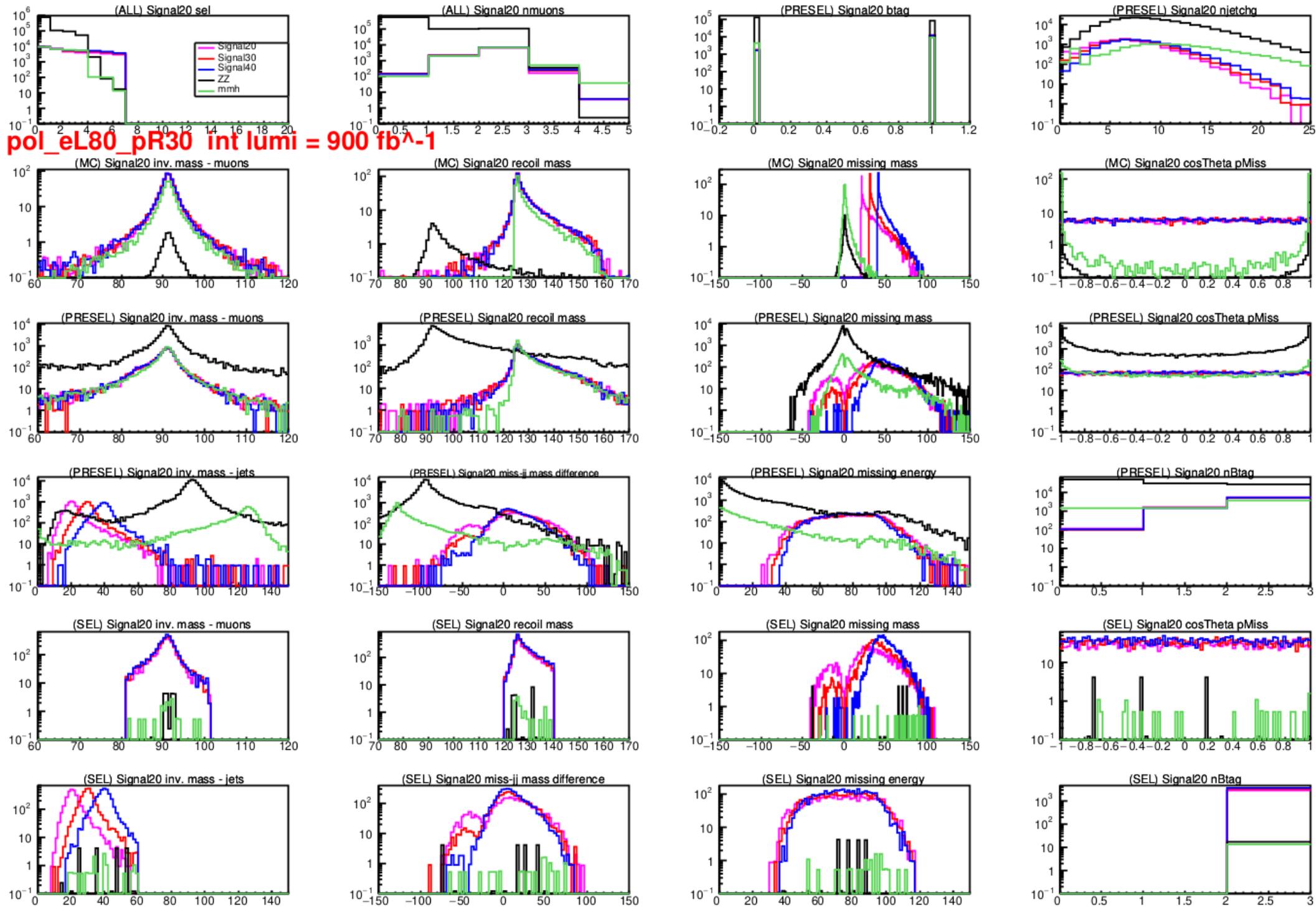


exercises to try now (or later):

add in the BSM signals with different φ masses
(un-comment the relevant lines)

add in the `zz_sl` and `mu-mu-h` backgrounds
(un-comment the relevant lines)

signal (m=20, 30, 40) ; ZZ background ; Higgs background

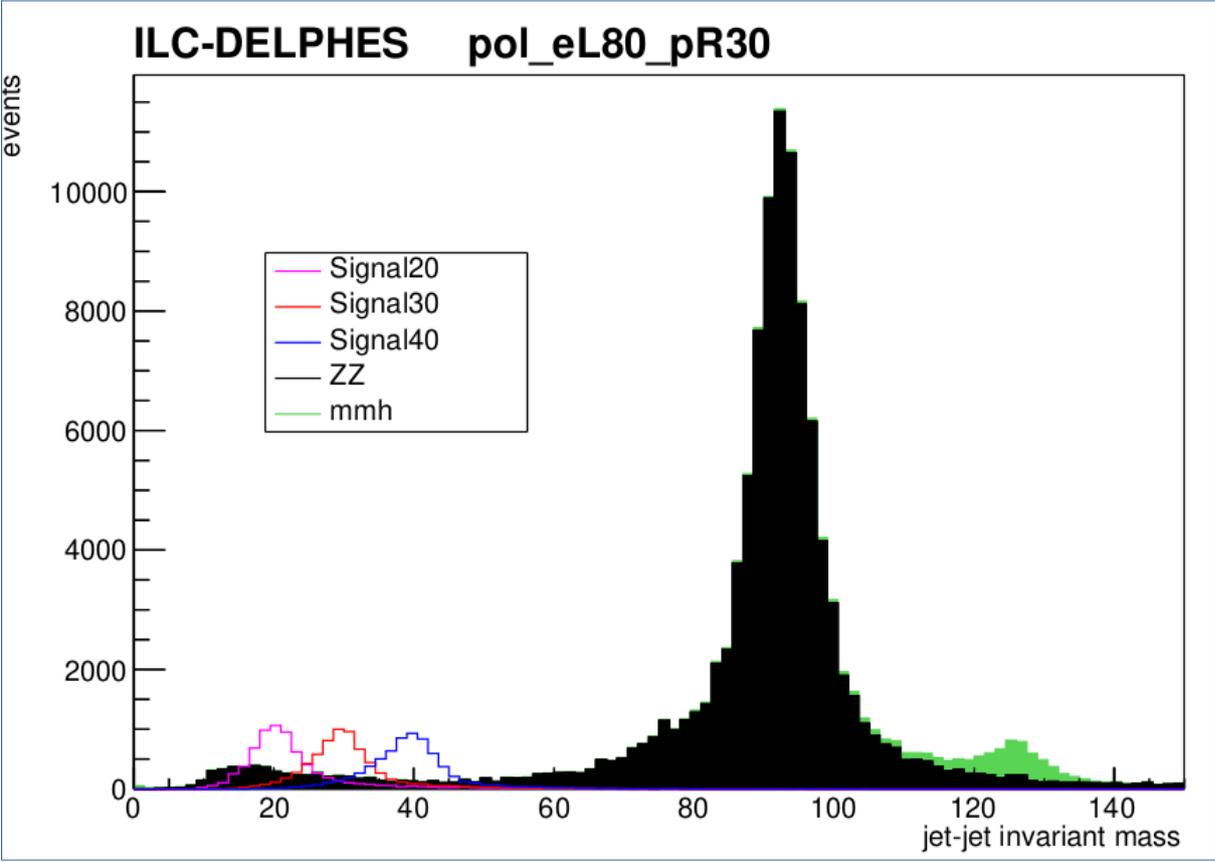


make a pretty plot for a note from histograms stored in the root file

/local-scratch/software/ilc_walkthrough/tutorial-code/makePrettyPlot.C

<https://research-up.kek.jp/people/jeans/snowmassSignal/makePrettyPlot.C> creates a pdf figure

```
$ root -b  
root [0] .x makePrettyPlot.C("walkthrough.root", "pol_eL80_pR30", "_PRE_jetmass", "jet-jet invariant mass" )
```



normalised assuming that $\sigma_{BSM} = \sigma_{SM}$

exercises to try now (or later):

convert into an upper limits on the BR for this exotic decay
for each polarisation set
(using your favourite statistical approach)

simplistic limit extraction

```

-----
EVENT cut table pol_eL80_pR30  int lumi = 900 fb^-1
-----

---SELECTION SUMMARY-----
...
CUT 7 ;  expected SM-BG events  30.7514  expected signal events (@ 100% BR) : Signal20  2918.49 ; Signal30  3332.84 ; Signal40  3688.61 ;
...

```

in eLpR polarisation part of ILC-250,
after selection expect

30.75 SM background events
3332.84 BSM signal events [$\sigma_{BSM} = \sigma_{SM}$, $m_\phi = 30$ GeV]

estimate expected 95% upper limit on
number of BSM signal events:

for $n \sim 30$, Poisson \sim Gaussian [mean μ , width $\sqrt{\mu}$]
→ 5% lies in range $0 < n < \mu - 1.64 \cdot \sqrt{\mu}$

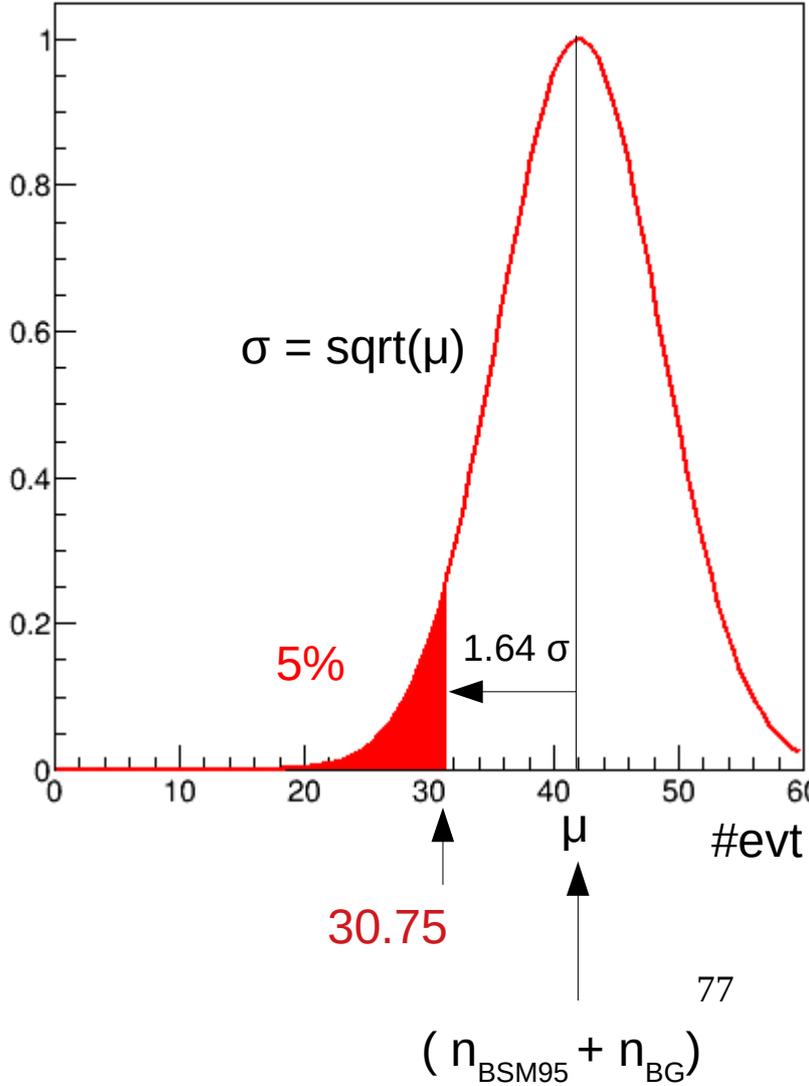
want expected 95% upper limit on $n_{95} = n_{BSM95} + n_{BG}$

$$n_{95} - 1.64 \sqrt{n_{95}} = 30.75$$

$$\rightarrow n_{95} = 41.3$$

$$\rightarrow n_{BSM95} = 41.3 - 30.75 = 10.6$$

→ 95% upper limit on
BR($H \rightarrow (\phi \rightarrow bb) (\phi \rightarrow invis))$
= $\sigma_{BSM} / \sigma_{SM}$
= $10.6 / 3332. \sim 0.3\%$



exercises to try now (or later):

look at the plots; adjust the cut values, add new cuts
(there are some commented-out suggestions in the code)

only few MC background events are selected
we are using only a fraction of available ZZ files available
→ use them all to reduce effect of finite MC statistics
(there are additional files on login.snowmass21 in the same directory)

calculate limits separately in the 4 polarisation sets

combined them into a single limit for the whole ILC-250 program
→ nb each set will have different sensitivity,
so don't just add SIG & BG for each set !

additional ideas:

the least-well measured objects in these events are the **jet energies**

one could apply a **constrained kinematic fit**:

- jet energies are free (or loosely constrained) parameters
- allow for net p_z due to ISR photon(s)
- impose 4-mom conservation
- impose jet-jet invariant mass = “invisible” mass
- impose higgs mass 125 GeV

.....

additional ideas:

this example used only $Z \rightarrow \mu^+ \mu^-$ decays

the much larger $Z \rightarrow \text{hadrons}$ channel is in general more sensitive

~ 20x more data, fully exploitable at lepton colliders

no dominant QCD background

→ will be collected [no trigger], and is useful

again because of trigger-less operation,

“all” **low momentum / displaced / appearing / disappearing**
particles are recorded and can be used

additional ideas:

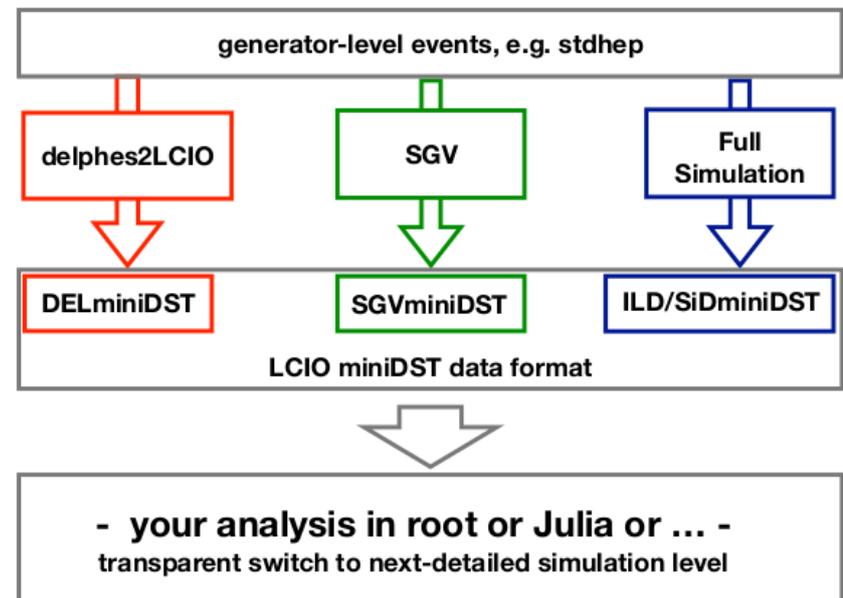
DELPHES applies a (carefully) parameterised momentum smearing
describes the central part of distributions pretty well,
but less good at the non-Gaussian tails

SGV-based fast simulation should give more realistic description

- signal samples at [/collab/project/snowmass21/data/ilc/analysis-walkthrough/signal/miniDST-SGV](https://collab/project/snowmass21/data/ilc/analysis-walkthrough/signal/miniDST-SGV)
- some changes required in the analysis code: they are documented there

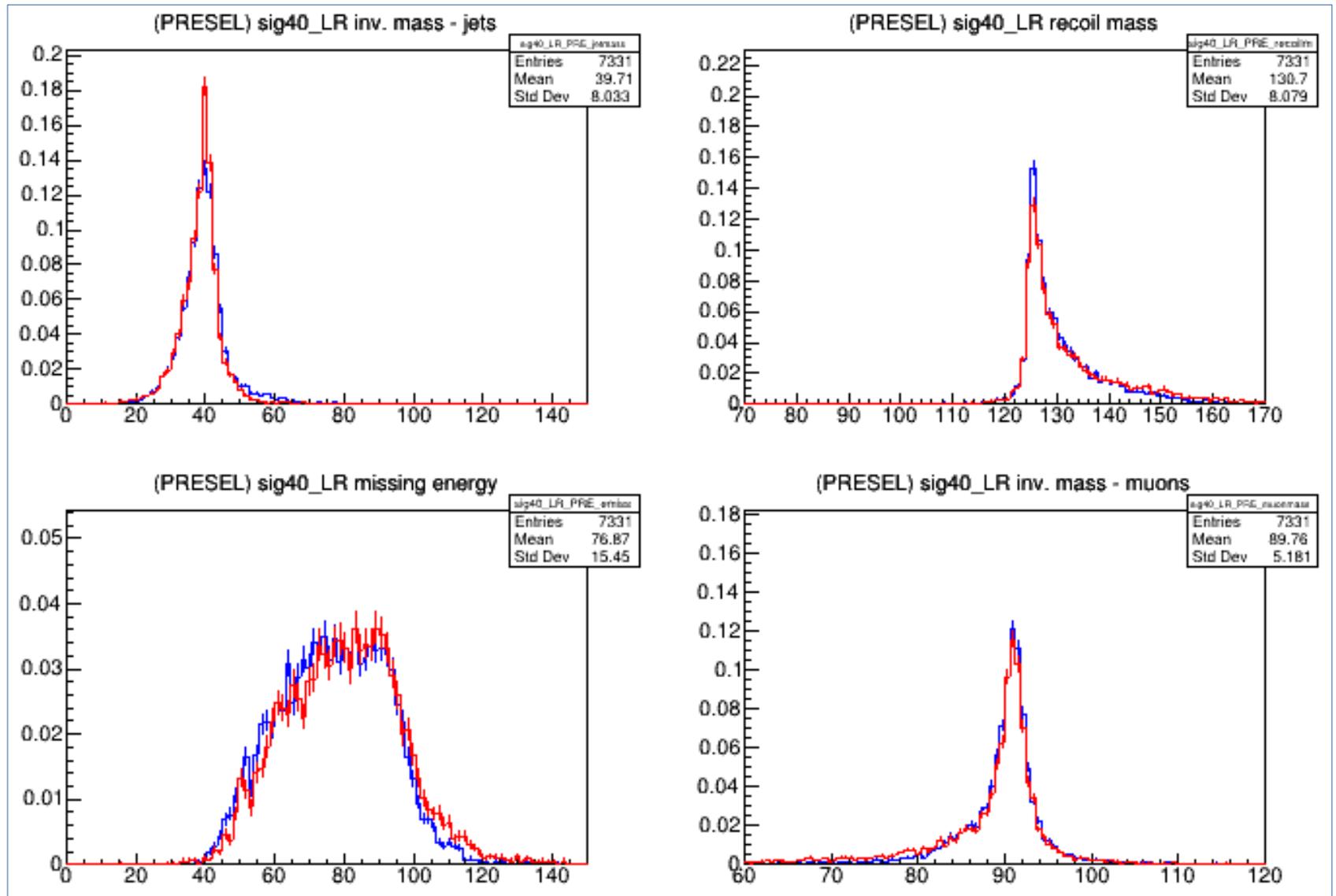
full Geant4 detector simulation of SiD / ILD concepts is most accurate

- **delphes2lcio**: an lcio application which makes Delphes (parametrised detector simulation) write out LCIO (<https://github.com/iLCSoft/LCIO/tree/master/examples/cpp/delphes2lcio>)
- **SGV**: Simulation a **G**rande **V**itesse (https://www.desy.de/~berggren/sgv_ug/sgv_ug.html) - detailed fast simulation from "first principles" (nearly no parametrisations!)
- **iLCSoft** (<https://github.com/iLCSoft>): software suite for full simulation and reconstruction of ILC & CLIC detectors



example: comparison of some observables in our signal sample (@40 GeV)

DELPHES vs. **SGV**



fully simulated MC data

there are very detailed Geant4 models of 2 detector concepts, SiD and ILD
these will give the most reliable estimates of ILC's potential

if you want to use such fully-simulated data,
we ask you to become
a “guest member” of
one of these concept groups

[you are welcome to join even
if you don't plan to use full-sim data]

To join the SiD group, please contact

- Spokespersons: Andrew White (awhite@uta.edu), Marcel Stanitzki (marcel.stanitzki@desy.de)
- Physics Coordinator: Tim Barklow (timb@slac.stanford.edu)

To join the ILD group, please contact

- Spokesperson: Ties Behnke (ties.behnke@desy.de)
- Physics Coordinators: Keisuke Fujii (keisuke.fujii@kek.jp), Jenny List (jenny.list@desy.de)
- Executive Team member from the US: Graham Wilson (gwwilson@ku.edu)

resources & help

<http://ilcsnowmass.org/> (developing) details of available samples etc

<https://arxiv.org/abs/2007.03650> links to current status reports &
lots of ideas for additional studies

#ilc-snowmass Slack channel

Contact information

- LCC Physics Working Group conveners:
 - Keisuke Fujii (keisuke.fujii@kek.jp), Christophe Grojean (christophe.grojean@desy.de)
Michael Peskin (mpeskin@slac.stanford.edu)
- ILC detector concept group physics coordinators:
 - SiD: Tim Barkow (timb@slac.stanford.edu)
 - ILD: Keisuke Fujii (keisuke.fujii@kek.jp), Jenny List (jenny.list@desy.de)
- ILC contacts for the various Energy Frontier working groups
 - EF01: Shin-ichi Kawada (shin-ichi.kawada@desy.de)
 - EF02: Maxim Perelstein (m.perelstein@cornell.edu)
 - EF03: Roman Poeschl (poeschl@lal.in2p3.fr)
 - EF04: Sunghoon Jung (sunghoonj@smu.ac.kr)
 - EF05: Juergen Reuter (juergen.reuter@desy.de)
 - EF08: Mikael Berggren (mikael.berggren@desy.de)
 - EF09: Taikan Suehara (suehara@phys.kyushu-u.ac.jp)
 - EF10: Aleksander Filip Żarnecki (Filip.Zarnecki@fuw.edu.pl)
 - TF07: Mihoko Nojiri (nojiri@post.kek.jp)
- Technical support: ilc-snowmass@slac.stanford.edu; ilc-snowmass on Slack

thanks for your attention!

